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ABSTRACT

These materials are designed for teachers participating in an inservice workshop on water quality. Included in the materials are a workshop agenda, a water awareness pretest, and the various parameters and tests that are used to determine and measure water quality. The parameters are discussed from the standpoint of their potential impact to domestic waters, wildlife, and aquatic life. A description of the chemistry of the parameters and procedures is included where applicable. These materials include two readers on water quality. The first reader discusses sewerage systems, both domestic and industrial, the problems associated with waste treatment, and a listing of the more significant definitions. The second reader presents measurements and eutrophication. After the second reader, there is a section on the interpretation of water parameter data, followed by a listing of student-oriented learning activities for possible inclusion into the curriculum. A bibliography and teacher workshop evaluation form conclude this workshop guide. (BT)

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TEXAS WATER QUALITY BOARD

TEACHERS WORKSHOP PROGRAM

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TEXAS WATER QUALITY BOARD

TEACHER WORKSHOP AGENDA

9:00 - 9:10	Introduction
9:10 - 10:00	Water Awareness Test
10:00 - 10:30	Film, "The Gifts"
10:30 - 10:45	Break
10:45 - 11:15	Role of Federal, State, and Local Governments in Water Pollution Control
11:15 - 12:00	Water Quality Parameters
12:00 - 1:00	Lunch
1:00 - 1:45	Wastewater Treatment Methods
1:45 - 2:30	Biological Responses to Water Pollution
2:30 - 2:45	Break
2:45 - 3:15	Film, "The Creek"
3:15 - 3:45	Social and Economic Factors Affecting Water Pollution Control
3:45 - 4:00	Conclusion and Evaluation

TEACHER WORKSHOP
WATER AWARENESS TEST

INTENT: This test is designed to stimulate a discussion of certain water quality concepts.

DIRECTIONS: Select the choice that you believe best completes the following questions or statements.

1. According to public opinion polls, are most United States adults concerned about pollution?
   1. Yes, and they are willing to pay to clean it up.
   2. Yes, but they are not willing to pay to clean it up.
   3. No, and they are not willing to pay to clean it up.
   4. Most U.S. adults have no opinion concerning pollution.

2. Which of the following properly rates the sources of water pollution in the United States, from greatest to least?
   1. Municipal, agricultural, industrial
   2. Industrial, agricultural, municipal
   3. Industrial, municipal, agricultural
   4. Municipal, industrial, agricultural

3. Which of the following is considered a major water pollutant?
   1. Human waste
   2. Chlorine
   3. Carbon dioxide
   4. Carbon monoxide

4. Which of the following compounds is most responsible for accelerating the eutrophication process in water?
   1. Calcites
   2. Iodides
   3. Phosphates
   4. Chlorides

5. Which of the following containers, if discarded today, could conceivably be found 50 years from now?
   1. Tuna fish can
   2. Plastic bleach bottle
   3. Cigarette package
   4. Large cardboard shipping box
   5. Pull-tab from a beverage can

6. Which of the following water nutrients is commonly found in fertilizers?
   1. Nitrates
   2. Sulfates
   3. Chlorates
   4. Carbonates

7. Coliform bacteria are most commonly found in
   1. Organic pesticides
   2. Wastes from warm blooded animals
   3. Forest soil
   4. Food

8. The least desirable feature of the use of phosphates in detergents is that
   1. Many people are allergic to them
   2. They may lead to excessive growth of vegetation in lakes and rivers
   3. They are poisonous to the beneficial bacteria in sewage treatment plants
   4. They do not clean clothing as effectively as do other products

9. What happens to the number of different varieties of fish in a stream as the pollution in the stream increases?
   1. It increases due to the addition of "trash fish."
   2. It remains the same, but with fewer fish of each variety.
   3. It remains the same, but the varieties change.
   4. It decreases.

10. As the human population increases, pollution problems per person actually
    1. Increase
    2. Stay constant, but seem to increase
    3. Stay constant, and appear so
    4. Decrease

11. Is it possible to control crop-destroying pests without also causing an adverse effect on air, land, or water?
    1. Yes, by spraying, but only in the spring of the year
    2. Yes, by spraying throughout the season, but only just before rainstorms
    3. Yes, by using the pests' natural enemies
    4. No

12. If phosphate detergents were outlawed, what would be the primary effect on existing nutrient enriched lakes, streams, and coastal waters?
    1. Their natural balance would be restored.
    2. They would become more fertile and therefore less polluted
    3. Some, but not all, of the phosphate enrichment would be stopped.
    4. The chemicals now being produced by the lakes to balance the phosphates would themselves become a problem.

13. Which do you consider the source of most of the world's oxygen?
    1. Trees and other forest plants
    2. Natural grasslands and farm pastures
    3. Tiny plants (phytoplankton) near the surfaces of oceans
    4. Plants, such as seaweed, growing at the bottom of the oceans

14. What is considered the best method to prevent the washing away of topsoil?
    1. Building canals
    2. Planting grasses
    3. Having cattle graze the land
    4. Building stone fences at the edges of fields

15. Problem-causing aquatic algae typically will grow most rapidly in waters whose temperature is best described as
   1. Cold (10° C)
   2. Cool (10-25° C)
   3. Warm (25-35° C)
   4. Hot (35° C)

16. If the amount of light reaching a body of water is reduced, the quantity of algae in that water will
   1. Increase, year round
   2. Decrease, year round
   3. Increase in the summer but decrease in the winter
   4. Increase in the winter but decrease in the summer

17. What has sometimes been called "the water crisis" in the United States is primarily due to which of the following?
   1. Poor water management
   2. A general water shortage
   3. A long-time drought
   4. Distribution of populations

18. In humans, the biochemical effects of DDT are compounded by its action on which of the following?
   1. Liver
   2. Heart
   3. Stomach
   4. Bones

19. Which of the following sources adds the greatest amount of phosphates to lakes?
   1. The processing of metal
   2. Plastic manufacturing
   3. Fertilizers
   4. DDT spraying

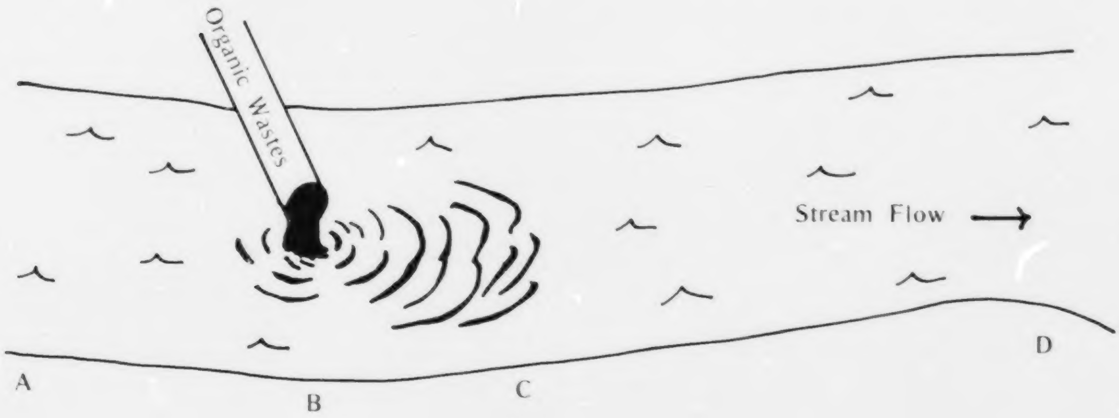
20. Do you know the location of your municipality's water and wastewater treatment plants?
   1. Yes
   2. No

21. Eutrophication occurs primarily in which of the following areas?
   1. Lakes
   2. The atmosphere
   3. Soils
   4. Oceans

22. The major threat to the survival of the Everglades comes from
   1. An overabundance of alligators
   2. Animal poachers

3. The introduction of exotic plant and animal species
4. The decrease in available water

23. Which of the following agencies is the state's principal authority on matters relating to the quality of the water in the state?
    1. Texas State Department of Health
    2. Texas Parks and Wildlife Department
    3. Texas Water Development Board
    4. Texas Water Quality Board
    5. All of the above



24. If four measurements of dissolved oxygen (DO) were taken in the above stream and values were found to be 1, 3, 6, and 8 mg/l, where would you expect to find the lowest DO reading?
    1. At points A & D
    2. At point B
    3. At point C
    4. At points C & D

25. Where would you expect to find the highest reading of DO?
    1. At points A & D
    2. At point B
    3. At point C
    4. At points C & D

26. What do you consider the ultimate basis for man's successful adjustment in the world ecosystem?
    1. Man's values
    2. Man's knowledge
    3. Man's resources
    4. Man's education

MEASURING WATER QUALITY

Water quality tends to be considered good when the water has the odor, taste, feel, appearance, and behavior that we expect or like for it to have; conversely, poor water quality is characterized by one or more objectionable, nuisance, or unexpected features. Historically, many cases of pollution have been obvious even to the untrained observer. Unsightly floating materials, garbage, scum, muck, etc. are considered clear indications of polluted waters. It does not require an environmental specialist to detect wastewater sludge eminating from an exposed sewer. There are many practical examples of obvious pollution which are easily detected.

Beyond the obvious sensual sources of water pollution lie many causes of pollution which while not quite as offensive from an aesthetic sense are very serious. There are the toxic elements like mercury, lead, and arsenic; there are the radioactive substances, and a growing list of new compounds such as insecticides.

The kind of complication that is the hardest to anticipate is the behavior of various elements and compounds during their successive travel through a food chain. Water with a given composition, drunk directly by humans, may be perfectly safe, but one or more substances in the water may be concentrated in the tissues of other water users, then concentrated again as one organism preys on another.

If the final predator is consumed by humans, toxic concentrations may take their toll. In a sense, then, the water may be satisfactory for direct use but dangerous when considered in terms of its total utilization.

The amounts of different kinds of dissolved mineral matter that can be safely consumed differ widely. The merest trace of lead or arsenic is dangerous because they are cumulative poisons, and, although the amount taken in a day might be harmless, the buildup over a period of years can produce chronic illness or death. Silica, one of the most common constituents of rocks, is a major dissolved mineral in many waters, yet it seems to have no physiological effect at all. Beer, for example, contains four to five times as much silica as most drinking waters, but is obvious from the quantities of beer that is consumed that silica has no adverse effects.

It is obvious that as concerned people require cleaner waters, sophisticated techniques will be required for water quality monitoring. It is no longer possible for pollution control agencies to use only visible observations to detect the presence of pollution. Advanced technology in monitoring systems and techniques will be required. Remote water quality monitors with instant telemetry to computer operations are and will continue to be used.

It would be extremely difficult and probably futile to attempt to apply all the known analytical procedures known that could be used in the study of water. Currently the total number of parameters in actual use varies from 30 to 50. Obviously, for a class of students to characterize or define certain properties, a choice of parameters must be made. The selection is based on the needs of the testing program, the available equipment, finances, personal motivation, time allotted, and to some degree the expertise of the instructor.

In practice, only a relatively few of the total number of available measurements are made routinely. Assays of radionuclides, pesticide elements, and most of the biological forms require sophisticated skills and techniques. Regardless of the site selection used in the water survey, the instructor and class should construct their monitoring program around their particular environment and the specific different kinds of information they need.

Tables 1, 2, 3, 4, and 5 identity groups of parameters according to common usage.

Chemical parameters are quite specific, can be quantified relatively quickly and precisely, and can be related to water quality requirements. The availability of commercial pollution kits provide effective approaches to rapid and reasonably accurate analysis, especially when time, facilities, and lack of trained personnel are limiting factors

This reference discusses some water quality parameters that may be utilized by teachers in studies relating to water quality management. It is not feasible to apply all analytical procedures to a given water sample, however, certain analyses are performed more or less routinely on water samples and are included here. The Texas Water Quality Board uses many of these parameters in studying water quality and when all are considered, they are capable of describing the water quality of a sample.

This resource includes a series of selected parameters and their common sources. The parameters are discussed from the standpoint of their potential impact to domestic waters, wildlife, and aquatic life. A brief description of the chemistry of the parameter and procedures with reference to test kits is included where applicable.

For public schools, commercial water pollution kits provide effective approaches to rapid, safe, and reasonably reliable analyses. These kits are most beneficial in areas where facilities and lack of trained personnel are limiting factors. The Hach kits have been used only as examples of the chemistry involved in the test; there are other methods listed in Standard Methods and various EPA manuals. The use of brand names does not indicate endorsement by the Texas Water Quality Board.

The assemblage of information has been taken from many sources and authors. As of the present time the references used in this manuscript are not complete, and the reader should bear in mind that the manuscript is merely a rough draft and proper citations will be included at a later date.

Table 1

NUMBER OF STORET LISTINGS FOR WATER ANALYSIS

Parameters by Group	Example	Number of Parameters in Group
General Physical & Chemical	Alkalinity, COD, Iron, Turbidity, Zirconium	149
Physical Observations	Algae, Foam, Oil	12
Radionuclides	Gross Alpha & Beta, Strontium-90	141
Microbiological	Coliform by MPN & MF, Total Plate Count	18
Organic Materials:		
Carbon Adsorption Data	Chloroform & Alcohol Extractibles	12
Natural Organics	Chlorophyll, Tannins	4
Synthetic Organics	ABS, Phenols	2
Halogenated Hydrocarbons	Aldrin, Heptachlor, Toxaphene	62
Phosphorated Hydrocarbons	Malathion, Parathion	10
Miscellaneous Pesticides	Silvex	8
Treatment Related Observations	Available Chlorine	6

Table 2
MINERAL CONSTITUENTS

Major Constituents	Minor Constituents
Calcium	Iron
Magnesium	Manganese
Sodium	Silica
Potassium	Aluminum
Carbonate	Phosphate
Bicarbonate	Fluoride
Sulfate	Nitrate
Chloride	

Table 3
TESTS USED FOR NON-SPECIFIC CHARACTERIZATION OF WATER PROPERTIES

Physical Properties	Chemical Properties	Esthetic Properties
Hydrogen Ion (pH)	Hardness	Taste
Conductivity	Alkalinity	Odor
Temperature	Acidity	Suspended Matter
		Color

Table 4
TESTS USED FOR CHARACTERIZATION OF WATER TRACE ELEMENTS

Common Elements	Scarce Elements	Rare Elements
Aluminum	Arsenic	Antimony
Barium	Cadmium	Beryllium
Boron	Chromium	Bismuth
Copper	Lead	Cobalt
Iron	Lithium	Selenium
Manganese	Molybdenum	Silver
Strontium	Nickel	Vanadium
Zinc	Tin	
	Bromide	
	Iodide	

Table 5
TESTS USED FOR CHARACTERIZATION OF WATER
"POLLUTIONAL-TYPE" TESTS

Nutrient Demand Tests	Specific Nutrient Tests	Nuisance-Type Tests	Miscellaneous (Taste, Odors, Toxicity)
Dissolved Oxygen	Nitrogen:	Sulfur:	Phenols
Biochemical Oxygen Demand	Ammonia	Sulfide	Cyanides
	Nitrate	Sulfite	Heavy Metals
Chemical Oxygen Demand	Nitrite	Grease & Oils	
Chlorine Demand	Nitrogen (Organic)	Detergents	
Total Carbon	Phosphorus:		
	Phosphate (Ortho)		
	Phosphate (Poly)		
	Phosphorus (Organic)		

TEMPERATURE

Temperature changes in bodies or streams of water may result from natural climatic phenomena or from the introduction of industrial wastes, such as distillery effluents or discharges of cooling waters used by many industries. The temperature is important, and sometimes critical, for many uses of water. It affects the palatability of water, treatment processes, the value of water for many industrial uses, including cooling processes and its suitability as a habitat for aquatic life.

Many state and interstate water-pollution-control agencies place restrictions on temperatures or allowable temperature increases.

The elevation of stream temperatures, especially as the result of spent cooling waters, may become a serious pollution problem. Additional heat may contribute to undesirable stream conditions such as decreased oxygen capacity, increased oxygen demand, anaerobic zones, putrefication of sludge deposits, and the growth of sewage fungus. Stream temperatures may also be increased by irrigation practices and the return of agricultural drainage. Temperature rises of 10 to 20°C have been reported. The return of cooling waters to underground aquifers has also been known to increase groundwater temperatures by 20°C.

The increase in temperature may affect aquatic organisms by increasing their metabolic rates. It will also affect the development of aquatic insects which may cause them to emerge in to a cold terrestrial environment.

ODOR

(see also Tastes)

Disagreeable odors and tastes in water are associated with the presence of any of a great variety of objectionable substances, particularly living microscopic organisms or decaying vegetation, including weeds, bacteria, fungi, actinomycetes, and algae; decaying organic matter; sewage; and industrial-waste products. Problems of odor and taste are very complex because the senses of smell and taste are intimately related and their responses are often difficult to differentiate clearly. In addition, it is frequently difficult, if not impossible, to identify the specific cause of an odor or taste, for many substances can cause what appears to be the same effect, or because mixtures of substances may be involved.

It would be impractical to attempt to make a complete list of all the types of industry whose waste products are potentially odoriferous in water supplies, but among them are the following: pulp and paper; explosives; petroleum, gasoline, and rubber; wood distillation; coke and coal tar; gas; tanneries; meatpacking and glue; chemicals and dyes; and milk products, canneries, beet-sugar, distillation and other food products. Among the chemicals responsible for tastes and odors are halogens, sulfides, ammonia, turpentine, phenols and cresols, picrates, various hydrocarbons and unsaturated organic compounds, mercaptans, tar and tar oils, detergents, pesticides, and innumerable others, many of unknown identify.

Waters free from odor and taste nuisance are desirable for drinking and domestic use, industry, irrigation, fish production and fishing, shellfish culture, and recreation. Odors and tastes are particularly undesirable in waters for drinking and domestic purposes, beverages, dairying, distilling, brewing, and other food-processing industries.

Offensive odors and tastes may be imparted to fish and shellfish from polluted waters by algae, petroleum products, turpentine, resins and resin acids, vegetable and mineral oils, insecticides, wastes from synthetic rubber and explosives factories, petroleum refineries, phenols, and cresols. Phenol in concentrations of 15 mg/l to 25 mg/l and cresols in concentrations of 10 mg/l have rendered fish unpalatable.

Many state and interstate water-pollution-control agencies have included references to odors and taste in their standards, but such requirements are qualitative.

TASTES

While taste responses are often difficult to differentiate from odor responses because the senses of taste and smell are closely inter-related, certain non-volatile substances dissolved in water can cause tastes without causing odors. To some extent, therefore, the subject of taste-producing substances in water may be discussed independently. Although no procedures for taste determinations are recommended by Standard Methods for the Examination of Water and Wastewater; threshold taste tests are made using techniques similar to those used for odor tests.

COLOR

Though not an exacting test, color does serve as a good indicator of pollution. Color in water may be of natural mineral or vegetable origin, caused by metallic substances, such as iron and manganese compounds, humus material, peat, tannins, algae, weeds, and protozoa. Waters may also be colored by inorganic or organic soluble wastes from many industries including nailworks, mining, refining, explosives, pulp and paper, chemicals, and others. Returned irrigation water also contributes to color.

In water-works practice, the true color of water is considered to be only that attributable to substances in solution after the suspensoids have been removed by centrifuging, because an accurate determination of color in water containing suspended matter is not possible. The term "apparent color" is used for color that includes an effect from suspended matters. However, the color of water with low turbidity is substantially the same as that of clear water. (Filtration has a decolorizing effect and should not be used to remove suspended matter). The unit of color considered as a standard is the color produced by the platinum-cobalt method of measuring, with the unit being one mg/l of platinum in water. Results are conventionally expressed as units of color, and not mg/l. The method is described in Standard Methods for the Examination of Water and Wastewater.

For high quality domestic water, some recommend that color be limited to 5 units while others would place the limit at 3 units of color. The stream standards promulgated by various state and interstate agencies limit the color in the raw water to be used as sources of drinking water to values ranging from none to 100 units. Some standards specify that color in the raw water shall not be in sufficient amount or of such character as to make the stream unsuitable as a source of water supply for drinking, culinary, or food-processing purposes, after reasonable treatment. In domestic water, color is undesirable from esthetic considerations and also because it may dull clothes, or stain food and fixtures.

The true color in water collected from unpolluted streams in Texas varies widely, from 10 units and less in West Texas to as much as 100 units in swampy streams in East Texas. A water containing 100 color units is quite noticeably colored while a water with a color of 10-15 units is not noticeably colored. Some industrial wastes may have colors ranging up to 1000 units.

A reddish-brown or yellow discoloration has been observed in sea waters where catastrophic mass deaths of fish and shellfish have been associated with the appearance of multitudes of certain poisonous plankton organisms, either algae or protozoa (red tide). Eutrophication of lakes, with concomitant production of algae, generally leads to increased color.

The Hach test for color is based on APHA platinum - cobalt standard. It reads apparent color which is created by dissolved substances within a range of 0-100 units.

SPECIFIC ELECTRICAL CONDUCTANCE

Natural inland waters usually contain in solution relatively small quantities of mineral salts, but in waters polluted by brines and various chemical wastes the salt concentration may rise to levels harmful to living organisms because of the increase in osmotic pressure. In studies of waters for use in irrigation and fish production, the salinity is often expressed as specific electrical conductance. The determination of conductivity is a quick method for measuring the ion concentration of water. Procedures and equipment are described by Standard Methods for the Examination of Water and Waste Water. Conductivity is reported as specific electrical conductance, the reciprocal of the resistance in ohms of a column of solution one centimeter long and with a cross section of one square centimeter, at a specified temperature, usually 25°C.

In fish studies, specific electrical conductance is reported directly as reciprocal ohms (mhos) at 25°C. Thus, a 0.005N solution of NaCl, 292.2 mg/l, has a specific electrical conductance, K, of 0.000604 mhos or 604 X 10^{-6} mhos at 25°C. In irrigation studies, however, it is customary to report specific electrical conductance as K X 10^5 or as EC X 10^6 at 25°C. For the 0.005N solution of NaCl, irrigation literature would report the conductance as K X 10^5 = 60.4 or as EC X 10^6 = 604. Considering the combined effects of all of the dissolved salts, it has been found that K X 10^5 values times 6.5, and EC X 10^6 values times 0.65, are approximately equal to the concentrations of dissolved salts in mg/l. Values of K X 10^5 divided by 10 are approximately equal to the concentration of cations or anions in equivalents per million (269). Where NaCl is the only salt, K X 10^5 values should be multiplied by 4.7 to 5.7 to give concentrations in mg/l, depending on the concentration.

Conductance is one of the most important criteria for the classification of irrigation waters. The limits suggested by various authorities are summarized in the following table:

SPECIFIC ELECTRICAL CONDUCTANCE OF IRRIGATION WATERS

Designation	EC$\times 10^6$ at 25°C in Micromhos per cm
Class I, suitable under most conditions	<1000 <750
Class II, suitability on crop, climate, etc.	1000-3000 750-3000
Class III, unsuitable under most conditions	>3000

Designation	EC$\times 10^6$ at 25°C in Micromhos per cm
Excellent	$<$ 250
Good	250- 750
Permissible	750-2000
Doubtful	2000-3000
Unsuitable	$>$ 3000

All substances in solution in the water collectively exert osmotic pressure on the organisms living in it, and the aquatic life is adapted to the conditions imposed upon the water by its dissolved constituents. Most species can tolerate some changes in the relative amounts of salts normally present if the total concentration is not exceeded. However, wide variations in the total salinity or in the concentrations of individual salts can have far-reaching effects upon stream fauna, resulting even in the elimination of species.

When the osmotic pressure is sufficiently high, owing to salts in solution, water may be drawn from gills and other delicate external organs, with considerable damage to cells, or even death. High concentrations of many kinds of pollutants present this danger apart from any other toxic or corrosive effects they may have.

Studies of inland fresh waters indicate that the specific conductance of streams and rivers supporting a good mixed fish fauna lay, in general, between 150 and 500 mhos X 10^{-6} at 25°C, except in streams of the western plains and desert areas, particularly those carrying the more alkaline natural waters. Such waters, draining land rich in soluble alkalis, were found to have a conductance as high as 5000 mhos X 10^{-6} at 25°C. However, good mixed fish fauna were usually not found in waters with a specific conductance greater than 2000 mhos X 10^{-6} at 25°C. On the basis of studies it has been concluded that conductances in excess of 1000 mhos X 10^{-6} at 25°C in most types of stream, or in excess of 2000 mhos in the alkaline western streams are probably indicative of the presence of acid or salt pollution of various kinds.

Among United States waters supporting a good fish fauna about 5 percent have a specific conductivity under 50 X 10^{-6} mhos at 25°C; about 50 percent under 270 X 10^{-6} mhos; and about 95 percent under 1100 X 10^{-6} mhos.

TURBIDITY

The turbidity of water is attributable to suspended and colloidal matter, the effect of which is to disturb clearness and diminish the penetration of light. Turbidity may be caused by micro-organisms or organic detritus; silica or other mineral substances including zinc, iron, and manganese compounds; clay or silt; or sawdust, fibers or other materials, either as a result of natural processes or erosion or as a result of the addition of domestic sewage or wastes from various industries, such as dredging, pulp and paper manufacturing, and others.

The turbidity of a water sample is a measure of the extent to which the intensity of light passing through is reduced by the suspended matter. Although in some of the literature the terms "turbidity" and "suspended solids" (or other equivalent words, such as "suspended matter" and "suspensoids") are used almost synonymously, the degree of turbidity is not equal to the concentration (or quantity) of suspended solids, but is an expression of only one effect of suspended solids upon the character of the water.

The measurement of turbidity recommended by Standard Methods for the Examination of Water and Wastewater is based upon a comparison of the amount of light passing through the given water sample with that passing through a standard sample. Turbidity is measured in standard units, defined in terms of the depth of water to which a candle flame can be clearly distinguished.

The 1962 USPHS Drinking Water Standards specify that turbidity shall not exceed 5 units. State and interstate agencies that have adopted systems of stream classification and standards sometimes designate limits for turbidity in streams that are used for domestic water supply, with values ranging from 5 to 250 units but most commonly the limits of turbidity are expressed in general terms.

Turbidity is undesirable in waters for laundries, ice making, bottled beverages and brewing, textiles, pulp and paper, steam boilers and turbine operation, and other industrial processes. Excessive turbidity in water affects fish by interfering with the penetration of light, it militates against photosynthesis and thereby decreases the primary productivity upon which the fish-food organisms depend. As a consequence, fish production is diminished. At very high concentrations, the particulate matter that produces turbidity can be directly lethal. By excluding light, turbidity makes it difficult for fishes to find food. Conversely, smaller fish may be similarly protected from predators. Turbidity modifies the temperature structure of ponds. Bottom temperatures are generally lower in turbid ponds than in clear ones. In many ponds, lower temperatures mean lower productivity.

SUSPENDED SOLIDS

In natural waters, suspended solids consist normally of erosion silt, organic detritus, and plankton. The impact of man's activities, however, alter and augment the suspended solids in surface waters by the discharge of liquid wastes from communities and industries, by increased erosion from deforested and cultivated areas, by gravel washings and by dusts that are blown into streams.

To differentiate between suspended solids and settleable solids is often difficult, because these two terms are often confused in the literature, although the method of determination of each is clearly described in Standard Methods for the Examination of Water and Wastewater. Strictly speaking, until they have settled to the bottom of a water course (or a laboratory sample bottle), all settleable solids are suspended solids. On the other hand, only a fraction of the suspended solids are settleable and this fraction is dependent upon quiescence, temperature, density, flocculation, and many other factors. In this section of the report only those references that deal strictly with the term "suspended solids" are considered.

Where stream classifications and standards have been promulgated, or where effluent standards are used, the test for suspended solids is generally employed as a significant criterion.

The 1962 USPHS Drinking Water Standards do not specify limiting concentrations for suspended solids, but such concentrations are indirectly controlled by the limits on turbidity (5 units) and total solids (500 mg/l). In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be in sufficient concentration to be objectionable or to interfere with normal treatment processes. Those agencies that employ effluent standards, however, are more specific in delineating concentrations (or percentage removals) of suspended solids in effluents.

Suspended solids in water interfere with many industrial processes, and cause foaming in boilers, or incrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries, paper and pulp, beverages, dairy products, laundries, dyeing, photography, cooling systems, and power plants.

Disregarding any possible toxic effects attributable to substances leached out by water, suspended solids may kill fish and shellfish by causing abrasive injuries; by clogging the gills and respiratory passages of various aquatic fauna; and by blanketing the stream bottom, killing eggs, young, and food organisms, and destroying spawning beds. Indirectly, suspended solids are inimical to aquatic life because they screen out light and because, by carrying down and trapping bacteria and decomposing organic wastes on the bottom, they promote and maintain the development of noxious conditions and oxygen depletion, killing fish, shellfish and fish food organisms, and reducing the recreational value of the water. It exerts a negative influence on photosynthesis and water temperature by reducing light penetration. Increases in suspended solids may follow a chain reaction sequence by providing bacteria contributing to turbidity with an abundant supply of nutrients required for growth and reproduction.

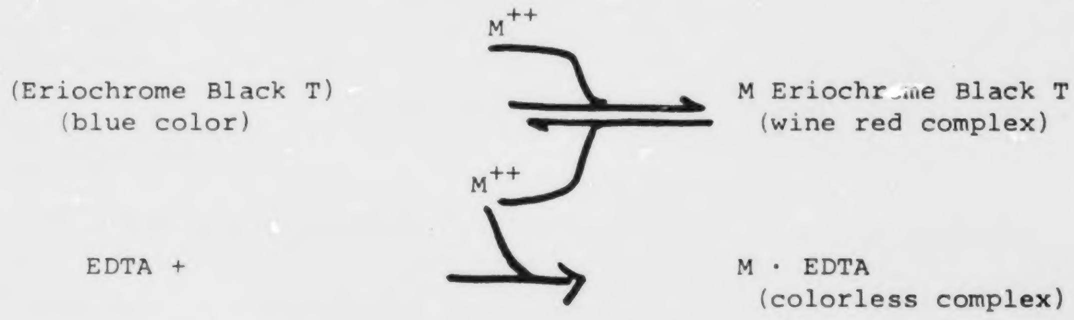
Suspended solids can be determined with a number of pieces of equipment. With the model 2100, Hach direct reading turbidimeter, a wide range of turbidity--from trace particles as low as 0.05JTU's to highly turbid waste sludge--can be detected. Turbidity is read directly in five different ranges on a single scale card inserted in the meter face. The turbidity is measured by comparing the interference to the passage of incident light in the questioned sample with that in a standard reference.

HARDNESS

Hardness is a water quality parameter affecting the lathering or foaming ability of soaps and increases the tendency of a sample to produce scale in pipes, heaters, and boilers. Water hardness may be caused by the natural accumulation of ions such as Calcium (Ca^{++}) and magnesium (Mg^{++}). Additional ions such as manganese (Mn^{++}) and iron (Fe^{++}) can also cause hardness but are present only in limited amounts of most waters. Although ions normally accumulate through soild and geological formulations, it may also be from direct pollution by industrial and commercial operations, and sewage. In good quality water, the total hardness is usually below 250 mg/l while hardness above 500 mg/l is considered unsuitable for general domestic purposes. The major detrimental effect of hardness is economic. Excessive ions, especially calcium is undesirable in water for laundries, beverages, dyeing and textile, food, etc.

The chemical determination of total hardness involves the titration of a sample to which an indicator, e.g. Eriochrome Black T has been added. The substance EDTA is used as the titrant due to its ability to complex with devalent ions. Prior to titration the indicator forms a red complex with Ca^{++} or Mg^{++}. During titration in a specific pH range the red indicator releases its bound cations to EDTA and reverts to its blue pigment. Total hardness is calculated from the amount of EDTA needed to reach the blue end point. In the determination of calcium hardness, magnesium is precipitated as magnesium hydroxide by the addition of alkali. The rest of the procedure is completed as outlined above. Magnesium hardness is calculated by subtracting the calcium value from the total hardness figure.

For total hardness, the Hach kit employs the following reactions:



(a) M^{++} = any divalent cation
(b) EDTA = ethylenediaminetetracetic acid.

Fa calcium hardness the following reaction is employed: Following the addition of sodium hydroxide a potassium hydroxide to precipitate magnesium hydroxide as follows, the reactions is as described above.

$$Mg^{++} + 2O\bar{H} \longrightarrow Mg(OH)_2$$

Magnesium hardness can be calculated by determining the difference between the total hardness and calcium hardness.

The hardness test kit gives a practical test range of 1ppm to 30ppm with an accuracy range of ± 5%.

pH

pH is a term used to express the intensity of the acid or alkaline condition of water. The pH scale ranges from 0 to 14, with pH 7 representing neutral conditions. pH values below 7 represent acid conditions. The intensity of the acid condition increases as the pH decreases. Similarly, alkaline conditions exist at pH values in excess of 7 and increase in intensity as pH values increase. Inasmuch as an excessive concentration of hydrogen ions may adversely affect water for one or more beneficial uses, pH is a measure of a potential pollutant. Not only is the hydrogen ion a potential pollutant in itself; it is also related intimately to the concentration of many other substances, particularly the weakly dissociated acids and bases. This means that pH controls the degree of dissociation of many other substances, particularly the weakly dissociated acids and bases. This means that pH controls the degree of dissociation of many substances which are frequently more toxic than the ionic forms. As such, pH may be a highly significant factor in determining limiting or threshold concentrations.

Most of the state agencies that have established stream standards or effluent standards have included limits for the pH values. The pH concentration of a raw water source for domestic water is important in that it affects taste, corrosivity, efficiency of chlorination, treatment processes, and industrial applications. The U. S. Public Health Service Drinking Water Standard of 1962 set no limits to pH in domestic waters.

The optimum pH for irrigation water depends on the type of crops to be grown and the physiochemical properties of the soil. Generally the areas where soils are alkaline, waters with low pH values are desirable. In acid soils, where liming is practiced, waters of moderately high pH are not detrimental for most crops.

Fish and other aquatic life seem more abundant in inland waters containing a pH range between 6.7 and 8.6. Of the United States waters that support a good fish fauna, 95% of the waters have a pH of less than 8.3. Fish are generally euryionic and can live in a wide pH range with limits as broad as 4.7 to 8.7. In addition, the pH existing in a water greatly affects the response of biological life to toxic chemicals. For example, the toxicity of some ammonium compounds toward fish have been found to increase by 200 percent or more when the pH is raised from pH 7.4 to 8.0 which may contribute to the total acidity or alkalinity of a given sample. It is essential to recognize that pH is not a measurement sensitive to the presence of substances which may contribute to the total acidity or alkalinity of a given sample. Consequently, it must not be confused with the results of total acidity and alkalinity determinations. Samples which possess a neutral pH may possess high acidity and/or alkalinity values. Because natural waters are buffered by the CO_2, HCO_3, CO_3 system to a pH range of 6.5 to 7.5, marked deviations from neutrality are generally the result of industrial contamination. Owing to their origin in municipal water supplies, most domestic sewages are neutral or slightly alkaline. Among the acid wastes may be included tan liquors, acid dyes, and some brewery wastes; and among the strongly alkaline wastes are laundry wastes, and bottle wash waters.

Most natural surface waters within the state have pH values within the range of 5 to 8.5 with the lower values usually existing in East Texas and the higher values in West Texas. Anything outside this range would generally indicate the presence of waste materials, although not in all cases.

The Hach kits utilize colorimetric procedures and are inexpensive, easy to use but accurate to only ± 0.1 pH unit at best. Electrometric techniques such as the pH meter yield the greatest accuracy. Whichever technique is used, the pH of a given sample should be obtained promptly to prevent changes due to reactions with CO_2 from the air or loss of CO_2 to the air.

DISSOLVED OXYGEN

Of all the water quality parameters, dissolved oxygen (DO) is one of the most significant for the determination of water quality. It is significant both as a regulator of aquatic plant and animal metabolism and as an indicator of water quality conditions. Dissolved oxygen in natural waters cannot rightfully be designated as a primary pollutant, but it does come under the category of a corollary pollutant because excessive DO arising from algal photosynthesis may adversely affect such waters for one or more beneficial uses. DO supersaturation is not of normal concern to the investigator although there is substantial documentation of increased incidence of mortality and disease in such waters. Rather our chief concern is with oxygen deficiency or complete absence thereof.

The content of dissolved oxygen at equilibrium with a normal atmosphere is a function of the temperature salinity and pressure of the water; the ability of water to hold oxygen decreasing with increases in temperature or dissolved solids and varying directly with pressure. DO can also be expected to change with depth, sludge deposits, turbulence, microbial tolerance, light, stability of sample, travel, mixing across the flow, and other factors. A single sample of dissolved oxygen rarely reflects accurately the overall condition of a body of water.

Oxygen is a gas and enters the water by absorption directly from the atmosphere or by green plant photosynthesis and is removed by respiration of organisms and by decomposition of organic material.

The dissolved oxygen in natural water normally ranges from 4 to 10 mg/l. For a diversified, warm-water biota such as we have in Texas, DO concentration should be above 4 mg/l. In some cases, good populations of fish, including game and pan fishes, occur in waters in which the dissolved oxygen may fall slightly below 4 mg/l for short periods. Three mg/l is too low, however, if normal growth and activity are to be maintained. No general statement can be made to give the minimum DO concentration required to support fish life, owing to the fact that the oxygen requirements of fish vary with the species and age of the fish, with prior acclimatization, with temperature, with the concentration of other substances in the water, and with several other factors.

The effect of oxidizable wastes on streams, the suitability of the water for fish and other organisms and the progress of self purification, all can be measured by DO determinations.

For the determination of dissolved oxygen, Hach utilizes the Azide modification of the standard Winkler Method with two improvements. For the test solution, phenylarseneoxide (PAO) is substituted for the sodium thiosulfate titrant which possesses a prolonged shelf life and is thus superior to sodium thiosulfate. The second improvement is the use of chemicals in dry powder pillows for the corrosive alkaline iodideazide solution, manganous sulfate solution, and the dangerous concentrated sulfuric acid solution. The Hach Model OX-2P is safe, easy to use, and the chemicals are stable.

The Hach kit utilizes the following reactions in the dissolved oxygen determination:

1) the oxygen is fixed according to the following reaction:
   $Mn^{++} + 2O\bar{H} + \frac{1}{2}O_2 \longrightarrow \underset{\text{(br. Floc)}}{MnO(OH)_2} \downarrow$ (eq. 1)

2) Sulfuric acid destroys interfering NO_2 by the sodium azide which was added in the alkali-iodide-azide reagent. The following reactions occur:

   $N_aN3 + H^+ \longrightarrow HN_3 + Na^+$ (eq. 2)

   $HN_3 + NO_2^- + H^+ \longrightarrow N_2 + NO_2 + H_2O$ (eq. 3)

   Under the same conditions, the M oxidizes I^- to produce I_2 as follows:

   $MnO(OH)_2 + 2I^- + 4H^+ \longrightarrow Mn^{++} + I_2 + 3H_2O$ (eq. 4)

3) titration of sample with PAO or sodium thiosulfate: The following reaction occurs:

   * $2S_2O_3^{--} + I_2 \longrightarrow S_4O_6^{--} + 2I^-$ (eq. 5)

   * Using starch as an indicator in the titration, an initial blue color will result indicating the presence of molecular iodine, I_2. Continue titrating until the molecular iodine is reduced to iodide ion as indicated by the disappearance of the blue color.

Each ml of sodium thiosulfate or PAO added in the final titration equals 1 mg/l (1ppm) Dissolved Oxygen. Because of the rapid absorption of oxygen from the atmosphere, suitable precautions must be taken in the collection and analysis of samples to secure valid measurements. Depending on the test method used, the accuracy of a carefully made measurement should range from ± 0.05 mg/l in natural water to ± 0.5 mg/l in polluted water with appreciable interference.

BOD--BIOCHEMICAL OXYGEN DEMAND

Most organic material found in water can serve as food for bacteria and other small organisms occurring in the water. Organic materials are compounds containing carbon, hydrogen, and other elements and which, in the main, have resulted from living organisms of some kind. Leaf mold, sewage, meat and blood wastes, molasses, chemicals such as alcohol, and manure are examples of organic materials. Inorganic materials generally do not derive from life processes, but are, in a sense, finely divided or dissolved rocks. The hardness in water and salinity in water result from inorganic dissolved solids. Some inorganic materials, such as nitrates, phosphates, and sulphates, can also serve as food for bacteria, especially when organic material is also present.

As the bacteria and other micro-organisms in the water consume as food the materials in the water, the organisms also consume oxygen just as a large animal consumes oxygen in breathing. The BOD test is simply a measure based on oxygen used by living organisms of the food available in water. In reporting results of a BOD measurement, low numbers mean that only a small amount of organic material is present, while the higher numbers represent larger amounts of organic material in the water. Since the test uses living organisms as the basis for measurement, the test is not overly precise and is affected by the fact that different organisms use various kinds of organic material as food at differing rates, and toxic materials can stop or slow the rate at which the micro-organisms can grow or use food. In most cases, natural waters, including those containing sewage, present no specific problems in making BOD measurements. Where the waters are salty or contain complex industrial wastes, difficulty in measurement may be encountered and special techniques may be required.

The laboratory determination of BOD consists of diluting a sample of the waste with water containing a known amount of dissolved oxygen, incubating this mixture at 20°C. in the air-tight bottle, and noting the loss of oxygen after a time lapse, usually 5 days. Although 15 to 20 days are usually required for the organic material to be substantially consumed, 60 to 70 percent of the material in most waste is consumed in five days, and the five day result has been acceptable as standard. Five-day BOD values are the values enumerated in the Water Quality Requirements. There is no standard against which the accuracy of the BOD test can be measured. In the range of values enumerated in the Water Quality Requirements, the BOD measurements can be reproduced within ± 20 percent.

The following are typical BOD values for various wastewaters:

Raw domestic sewage	100 - 300 mg/l
Well treated domestic sewage	10 - 20 mg/l
Blood	3000 - 5000 mg/l
A natural stream in good condition	0.5 - 4 mg/l

The Hach manometric method for BOD is a method in which a confined supply of effluent is agitated for a period of time, while the oxygen consumed by the oxidation of organic matter is continuously measured by means of a loss of pressure in the system.

The loss of pressure is registered on a mercury manometer, so that it is possible to make readings of the progression of the BOD during the incubation period. The Hach kit operates on the same principles as the Warburg apparatus, but is modified to contain the following improvements:

1) the manometer system operates independently of changes in barometric pressure and temperature
2) no training is required for operation
3) no mathematical calculations are required
4) has places for five samples so that one sample may be set each day for a continuing round of 5-day BOD tests
5) readings may be plotted on a graph which gives a great deal of information about the nature of the waste

BOD is important only insofar as it produces septicity or decreased dissolved oxygen, or subsequent growth of saprophytic bacteria which increases the turbidity or other undesirable characteristics of the water. Each water must be considered in its own right, and until the reaeration characteristic of the water is known the limiting values of BOD cannot be set.

NITRATES

Nitrates are the end product of the aerobic stabilization of organic nitrogen, and as such they occur in polluted waters that have undergone self-purification or aerobic treatement processes. Nitrates also occur in percolating ground waters as a result of excessive application of fertilizer or leachings from cesspools. In a few instances, nitrates may be added to a stream or ground water by natural degradation or directly by inorganic industrial wastes, but such sources are relatively insignificant. Wastes from chemical fertilizer-producing plants (apart from fertilizers in the field) are an increasingly important source of nitrate pollution.

In spite of their many sources, nitrates are seldom abundant in natural surface waters, for they serve as an essential fertilizer for all types of plants, from phytoplankton to trees. Photosynthetic action is constantly utilizing nitrates and converting them to organic nitrogen in plant cells. In deep ground waters, however, this action is not possible and, consequently, it is in such waters that excessive and deleterious concentration of nitrates are often found.

Until 1962, the USPHS Drinking Water Standards did not have a requirement for nitrates. At that time, however, a recommended limit of 45 mg/l as nitrates was established. This limit was established because of the relationship between high nitrates (or nitrites) in water and infant methemoglobinemia. No cases of such poisoning have been evident in the U.S. when the water consistently contained less than 45 mg/l of nitrate as NO_3 or 10 mg/l as nitrogen.

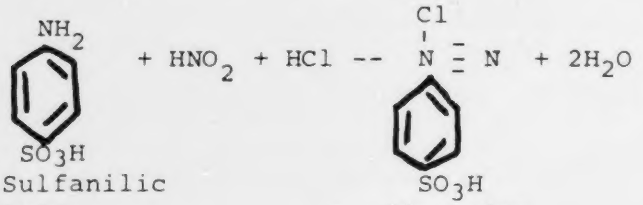
High nitrate concentrations in effluents, and water stimulate the growth of plankton and aquatic weeds. By increasing plankton growth and the development of fish food organisms, nitrates indirectly foster increased fish production. United States waters supporting a good fish life will seldom if ever exceed 4.2 mg/l of nitrate and will range as low as 0.2 mg/l of nitrate or less.

Nitrates are measured by reduction by cadmium to nitrite ions followed by a reaction with sulfanilic acid to form a diazonium salt. The salt is reacted with 1- napthylamine hydrochloride to form a red colored azo dye. The presence of nitrite ions in the original water sample will cause erroneously high nitrate values. A correction is achieved by measuring the nitrite value from the nitrate value obtained in the cadmium reduction.

The Hach nitrate test kit uses the above reduction method with the reactants included into a single powdered reagent. The test is simple and easy to conduct and is more accurate than previous tests, ranging 0-1, 0-10, and 0-100 mg/l nitrate nitrogen. This test method registers both nitrate and nitrite nitrogen. If nitrite is present in more than a trace, compared to the nitrate, a pretreatment of the sample is required.

The Hach kit utilizes the following reactions:

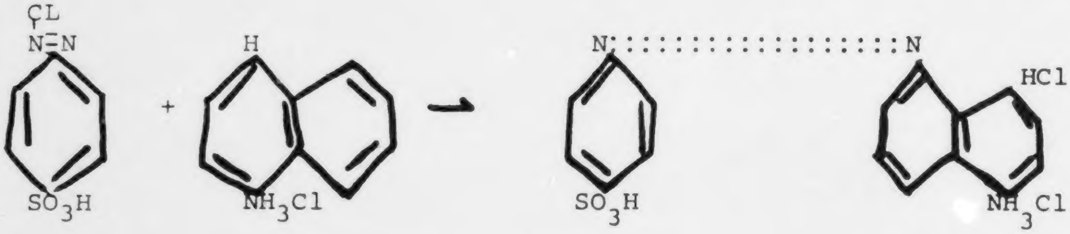
$NO_3^- + Cd = \overline{NO}_2 + CdO$ (Eq. 1: reduction of NO_3)



Sulfanilic Acid

diazonium salt

(EQ 2: diazotization)



Diazonium Salt

1-Napthylamine hydrochloride

a red-colored azo dye

Ammonia is a product resulting from the decomposition of nitrogenous organic matter, being another constituent of the complex nitrogen cycle. Although generally present in surface or ground waters as a result of such decomposition, it may result from the discharge of industrial wastes from chemical or gas plants, ice plants, or from cleaning operations where "ammonia water" is used. Waters known to be substantially free of pollution have very low ammonia concentrations, usually less than 0.2 mg/l. Being soluble in water, ammonia reacts with water to form ammonium hydroxide. This, in turn, dissociates readily into ammonium and hydroxyl ions, thereby tending to raise the pH value of the solution.

No limits on ammonia are set by the USPHS Drinking Water Standards of 1962, but a generally accepted limit for free ammonia for sanitary purity of water supplies is between 0.05 and 0.10 mg/l. There appears to be no physiological harm in concentrations of ammonia that might occur in natural or polluted waters.

According to many references, the toxicity of ammonia and ammonium salts to aquatic animals is directly related to the amount of undissociated ammonium hydroxide in the solution, which in turn is a function of pH. Thus, a high concentration of ammonium ions in water at a low pH may not be toxic, but if the pH is raised toxicity will probably increase.

PHOSPHATES

The phosphate ion exists both in organic and inorganic forms. With the exception of bottom sediments, and samples containing algae and suspended particles which may possess organic phosphorous as a major phosphorous form, emphasis is placed on evaluations of the inorganic forms. The sodium, potassium, and ammonium phosphates are soluble, but of the calcium salts only monocalcium phosphate is soluble. Most of the numerous magnesium phosphates are only slightly soluble.

Phosphates may occur in surface or ground waters as a result of leaching from minerals or ores in natural processes of degradation or from agricultural drainage, as one of the stabilized products of decomposition of organic matter, as a result of industrial wastes, as a constituent of cooling waters that have underground phosphate treatment and as a major element of municipal sewage as a result of utilization of syndets. In surface waters, however, phosphates are seldom found in significant concentrations because they are utilized by plants and converted into cell structures by photosynthetic action. Higher concentrations are likely to occur in ground waters that receive leachings from excessive application of fertilizer, from cesspools, or from the recharge of cooling waters.

Inorganic polyphosphates have been used in municipal water works and especially in boiler-feed-water treatment to prevent scale formation and to inhibit corrosion. There are numerous references dealing with such treatment, the preferred compounds, the optimum doses, and the results; but a review of such treatment is beyond the scope of this report. The subject is relevant to this survey, however, in that such treated waters may be discharged to streams or underground basins. In the concentrations encountered in water treatment, these polyphosphates do not appear to have any physiological significance.

The determinations of polyphosphates, orthophophates, and organic phosphate are considered significant because of our increased awareness of their role in life processes (ATP, enzyme function, buffers), combined with their use as fertilizers, detergents, water softeners, and the fact they encourage after growths of organisms in treated water by serving as a nutrient.

The discharge of excessive amounts of phosphates to streams or lakes may result in an overabundant growth of algae with concomitant odors and detriment to fish. In themselves, however, phosphates seldom exhibit toxic effects upon fish and other aquatic life and may be beneficial to fish culture by increasing algae and zooplankton.

Organic phosphates are used extensively in pesticides, and as such exhibit selective toxicity to many forms of aquatic life.

The Hach Company has several phosphate test kits depending on what the teaching intent is. Normally, procedures detect only orthophosphates but Hack's Deluxe Kit determines ortho, poly, and organically bound phosphate. If analyzing for total inorganic phosphate, the instructor or student will find it necessary to convert the polyphosphates to the ortho form if a reliable measure is to be obtained.

Detection of the orthophosphate form of phosphorous is accomplished by reacting it with ammonium molybdate to form ammonium phosphomolybdate. This product is subsequently reduced to molybdenum blue by reaction with stannous ions.

The Hack kit for orthophosphate utilizes the following reactions:

$$\overset{---}{PO_4} + 12\ (NH_4)_2\ M_oO_4 + 24H^+ = (NH_4)_3\ PO_4 \cdot 12\ M_oO_3 \quad \text{(Eq.1)}$$

$$(NH_4)_3\ PO_4 \cdot 12\ M_oO_3 + S_n^{++}\ \text{--}\ \text{Molybdenum blue} + S_n^{+4} \quad \text{(Eq. 2)}$$

CHLORIDES

Chlorides as chloride ions occur in practically all natural waters in widely varying concentrations. They may be of a natural mineral origin or derived from (a) sea water, (b) oil field brines, (c) human and animal sewage, and (d) industrial effluents such as those from paper mills, galvanizing plants, water softening plants, oil wells, and petroleum refineries.

Restrictions on chloride concentrations in drinking water are generally based on palatability rather than on health. In industry, chlorides appear to exert a significant effect on the corrosion of metallic pipes and structures. Chlorides are considered to be one of the more troublesome aspects in irrigation, whereas stock and wildlife appear to tolerate a relatively high concentration of chlorides.

For public supplies, the water is classified as "acceptable" if the chloride concentration is less than 125 mg/l, "doubtful" if between 125 and 250 mg/l, and "unsatisfactory" above 250 mg/l. For industrial needs, the corresponding limits are less than 50, 50-175, and over 175 mg/l respectively. A chloride level of 1500 mg/l is considered safe for stock and wildlife and levels of 100 mg/l are considered safe for irrigation purposes. On the basis of current information, chloride concentrations of 50 mg/l would be suitable for any use.

The chloride test may be performed by the Hach "Drop Count" tetration using the Mohr Argentometric Method described in Standard Methods pages 96-97. The titrating reagent is a silver nitrate solution, which is added to the sample using a calibrated dropper. A powdered chromate indicator, containing the proper pH buffer is used. The buffer indicator powder is packaged in powder pillows and one pillow is used in each test. Results are expressed as mg/l (ppm) sodium chloride. Depending on the specific needs of the experimentor, chloride concentrations can be determined to within 80-96% accuracy at commercial laboratories.

In tidal areas such as basins and bays, the natural chloride concentration is a result of the area's topographical and hydrological character. The chloride concentration may range from high salinity estuaries, such as Laguna Madre (30,000 mg/l) to low salinity estuaries, such as Sabine Lake (2,000 mg/l).

The Hach kit utilizes the following reactions:

1) $Hg^{++} + 2cl^{-} \rightarrow Hg\ cl_2$

2) Hg^{++} + Diphenylcarbazone = purple complex

The silver nitrate solution added to a water sample with the indicator combines with the chloride ions until the chloride supply is essentially depleted. At this point, silver ions form a colored complex by reacting with the indicator. The amount of silver nitrate solution added indicates the chloride ion concentration.

SULFATES

Sulfates occur naturally in waters as a result of leaching from gypsum and other common minerals. Sulfates of sodium, potassium, and ammonium are highly soluble in water and can be accumulated in rather high concentrations, in excess of 100,000 mg/l under certain conditions. The sulfates of lead, barium, strontium, and calcium are relatively insoluble. Sulfates may also occur as the oxidized state of organic matter in the sulfur cycle, but they in turn, may serve as sources of energy for sulfate-splitting bacteria. Sulfates may be discharged in numerous industrial wastes, such as those from tanneries, sulfate-pulp mills, textile mills, and other plants that use sulfates or sulfuric acid.

Public Health Service water standards call for not more than 250 mg/l of SO_4. But, public water supplies with higher sulfate content are commonly used with no adverse effects, and this limit does not appear to be based on tests or physiological effects of other than a laxative action for new users. The taste threshold of magnesium sulfate is 400-600 mg/l and for calcium sulfate is reported to be 250-800 mg/l. Excessive concentrations (1,000-2,000 mg/l) of magnesium sulfate may have purgative effects. A limit of 300-600 mg/l of sulfate is generally recommended for irrigation as they are somewhat less toxic than chlorides in irrigation waters. A threshold limit of 1,000 mg/l is recommended for stock and wildlife watering. In U.S. waters that support good game fish, 95% of those waters contain less than 90 mg/l.

Sulfates may be either beneficial or detrimental in manufacturing water. In brewing, sulfate aids in flavor production whereas in the ice industry it is undesirable due to causing white spots.

Accurate results in sulfate testing are obtainable using a Hach SF-1 kit. The test kit is a modified barium sulfate turbidimetric method using Sulfa Ver 111 powder pillows. The readout of this test encompasses sulfate levels from 35-200 mg/l. Within this range, the preciseness of the test is within 10%.

The Hach kit utilizes the following reaction:

$$Ba^{++} + SO_4^{--} \rightarrow BaSO_4$$

Then Ba^{++} + Indicator = orange-red complex

BACTERIOLOGY

Total coliforms include a group of bacilli microbes characterized by their ability to ferment a sugar (lactose) at 35°C. within 48 hours. Although coliforms are introduced to water supplies through soil runoff, drains, etc., they are considered significant as indicator organisms because of their predominance in the intestinal tracts of warmblooded animals and amphibians. The direct search for the presence of a specific pathogens in water is too slow, uneconomical, and unwieldy for routine purposes. Therefore with the advent of coliform analysis, water could easily be studied to determine whether it was potentially dangerous.

Since 1936, the number of coliforms present have been expressed generally in terms of the most probable number (MPN: most probable number of coliform bacteria per 100 ml), a value now regarded as relatively precise though still subject to error. This test does not measure the total number of bacteria, but only the number of coliform bacteria, those organisms found in the intestinal tract of all warm blooded animals, including humans. However, this test gives a good idea of the number of harmful bacteria that might be present. Guidelines have been established to evaluate the significance of MPN values. These guidelines, some of which are shown below, should only be used with judgment and should be supplemented in all cases with a physical inspection of the watershed for the type of pollution sources present.

The MPN determination is made by placing small amounts of the sample in each of several test tubes that contain a selective nutrient broth suitable for growing coliform bacteria. After the test tubes are incubated for 24 and 48 hour periods, they are observed to see how many of them are "positive" (actually having bacteria growing in them). When this is known, the results can be compared to statistical tables to find the most probable number of these coliform organisms. This test is reliable, although it does not measure the exact number of bacteria, as though you counted them one by one. It only gives an "idea" of how many are "probably" present, and its accuracy depends on how many test tubes of broth were used to perform the test (the more tubes used, the greater the accuracy).

The following MPN values will give an idea of what can be expected, or what is required, under certain circumstances:

Guideline Values	
Acceptable limit for raw water supply	less than 20,000
Acceptable limit for water contact recreation	less than 1,000
Acceptable limit for oyster harvesting	less than 70
Acceptable MPN for drinking water	less than 1

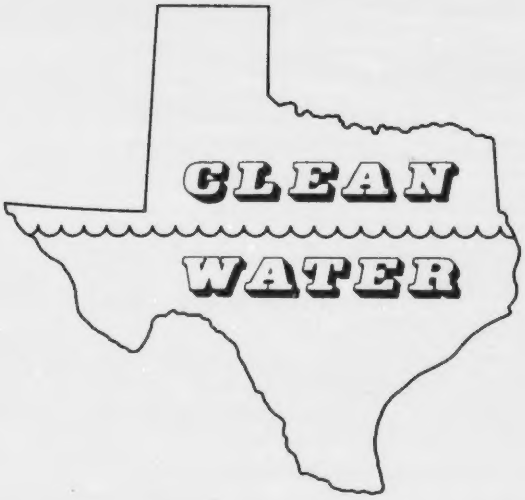
Typical Values	
Raw Sewage	10 to 20 million
Completely treated, unchlorinated sewage	1 to 10 million
Completely treated, chlorinated sewage	100 to 10,000
Salt water in Texas bays and estuaries	less than 10

The total coliform density is roughly proportional to the amount of excremental waste present. With exceptions, elevated coliform populations are suggestive of significant contamination by excretions of warm blooded animals.

Fecal coliform, a component of the total coliform population, is characterized by its ability to reproduce on a restrictive medium (MFC) at a temperature of 44.5°C. Because non-fecal coliforms may grow at temperatures below 44°C., and fewer fecal coliforms grow above 45°C., temperature maintenance within the specified tolerance is critical.

The fecal coliforms are gaining notoriety as pollution indices because of their relatively infrequent occurrence except in association with fecal pollution. Moreover, because survival of the fecal coliforms is shorter in environmental water than for the coliform group as a whole, substantial fecal coliform counts indicate relatively recent pollution.

The APHA coliform bacteria test has been adopted into a Hach kit. The test uses two different types of prepared and sterilized tube assemblies: the Presumptive (lactose broth) and Confirmed (brilliant green lactose bile broth) tubes. An advantage of these tube assemblies is that they are sterilized and packaged in sterilized packages for immediate use. The broth tubes are completely stable and will maintain their stability well over a year. A further advantage of the use of these coliform test tubes is that the test can be conducted immediately after collecting the water sample without storage or transport of the sample. This results in the greatest sensitivity and reliability as coliform bacteria die rapidly during aging of a water sample. Detailed instructions for potable water are supplied with each order and instructions for conducting dilution procedures is available upon request.


CLEAN
WATER

FIRST READER ON WATER QUALITY

THE TEXAS WATER QUALITY BOARD AUSTIN, TEXAS

Agency Publication Number 67-01

FIRST READER ON WATER QUALITY

PREPARED
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FOR THE

TEXAS WATER QUALITY BOARD

MARCH, 1967

FIRST READER ON WATER QUALITY

This pamphlet will discuss, in brief, sewerage systems, both domestic and industrial; the more common problems associated with waste treatment and collection; and a listing of the more significant definitions. It is not intended that this "First Reader" be considered as a text, for the subject matter which we treat here so briefly can be found in several hundred textbooks and articles. For the reader who desires more information, an abbreviated list of books follows this discussion.

BASICS:

Wastewater is a term which includes domestic sewage, industrial wastes, wastes from agricultural practices such as feedlots and irrigation tail waters, and any other unwanted liquids. Many years ago when our nation was young and only a small number of people were here, wastes could be put into the nearest stream and not even noticed. As our population increased and cities developed, the wastes released became more and more obvious. Today, we see a rapidly climbing population, all of whom must dispose of many gallons of waste each day. Since the flow in our streams cannot increase because rainfall does not change appreciably, the wastes have a greater and greater impact on our streams.

Since this problem has developed over a period of years rather than instantaneously, we have seen the construction of waste treatment facilities to help reduce the problem. Some areas of the country with larger stream flow have not provided the same degree of treatment as have water-short areas.

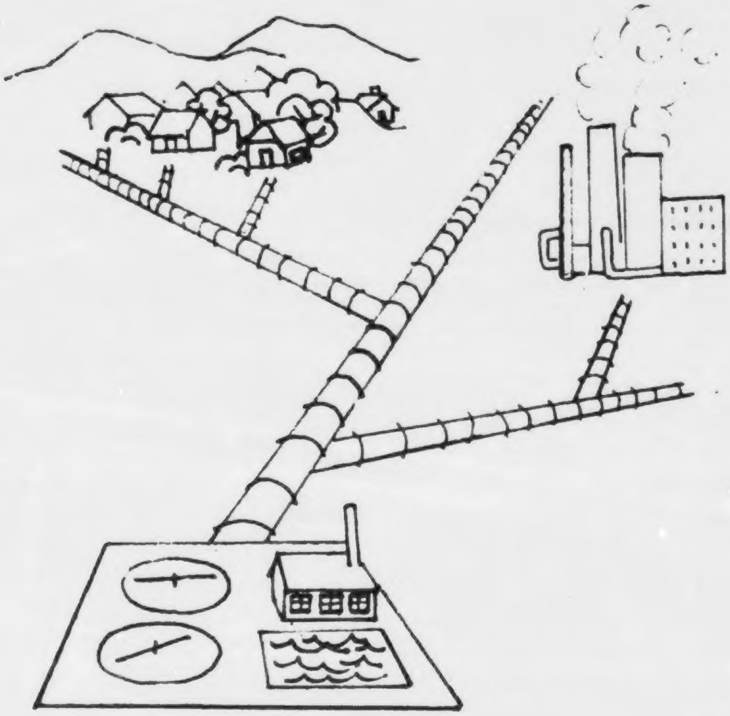
DOMESTIC SEWERAGE SYSTEMS:

A sewerage system is two things: the collection system and the treatment works. Individually, they are the sewage collection system and a sewage treatment plant. Together, they form a sewerage system. Domestic sewage is composed of 99.9% water and 1/10 of 1% of such things as dirt, grease, human waste, etc. Don't be misled by that 0.1% however, for in one million gallons of sewage, there is about five tons of solid material. The amount of sewage from a typical community will be very close to 100 gallons per person per day. You could expect then that a city of 10,000 people would generate 1,000,000 gallons of sewage a day.

This waste material from a city can be broken down into two basic parts: organic matter and inorganic matter. Inorganics are sand, rubber, metal, etc. Organics include food scraps, grease, human waste, etc. From this description of organic matter, it is obvious that some of it is in such a form that it can't be seen by the eye -- similar to sugar dissolved in water. Those materials which dissolve in water are called dissolved solids; and the other solids, such as sand, etc., are called suspended solids. Coffee grounds in coffee are suspended solids, and sugar in coffee is dissolved solids.

COLLECTION SYSTEM:

In a typical home, the sink, tub, etc., are connected to the house drain line, which normally has an inside diameter of four inches. The house drain line connects to a sewer line, usually in the street, but sometimes in the alley. These lines, as are all such lines except for one special group, are constructed to have a slight slope so that the sewage will flow naturally or by gravity for as long a distance as possible. The ideal situation would be one in which a city is located on the side of a hill so that all wastes could flow by gravity to a treatment plant at the end of the system -- as the sketch shows:

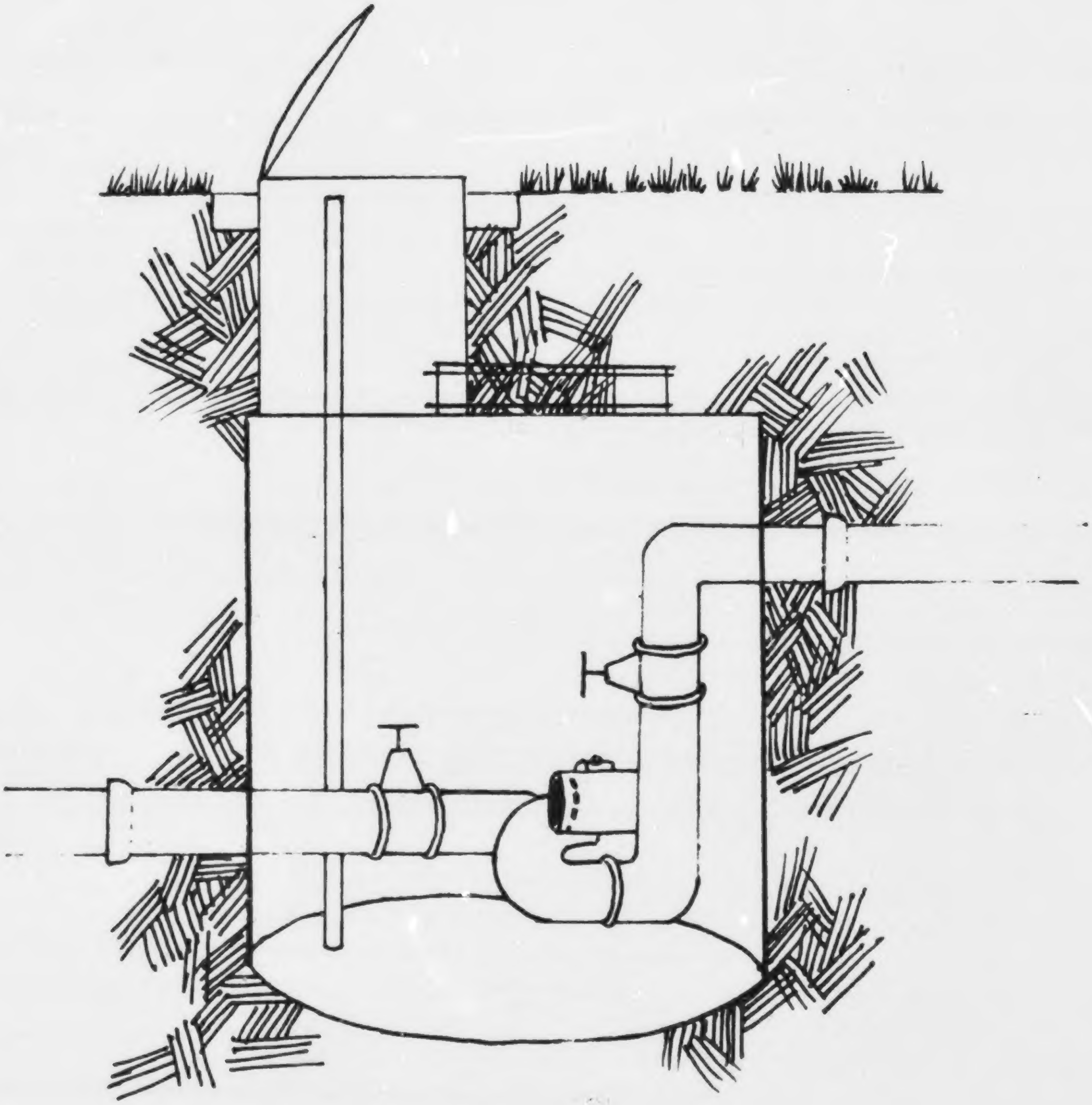


The street lines are then connected to lateral lines, thence to trunk lines, and finally to interceptor lines which carry the sewage to the treatment plant. The lines are usually constructed with enough slope to provide a velocity of two or three feet per second. This is necessary so that solids will not settle out of the water to the bottom of the line and then cause stoppage, and also to move the sewage as quickly as possible to the treatment plant.

Where there is no natural slope to follow or when hills block the path of the natural flow, the pipes must get deeper and deeper in the ground to maintain the necessary slope. When the line gets too deep to construct economically, the sewage must be lifted up by pumps so that it can start on its downhill path again. The pumps and controls which do this are called lift stations.

STORM SEWERS AND LINE JOINTS:

The storm sewer system, which carries off rainfall, is not normally connected to the sanitary (domestic) sewer lines. The sanitary sewage system collects wastes from houses, offices, industries, etc., and takes this waste to the sewage treatment plant. The storm sewer collects rain runoff and carries it to the stream close to town. This storm water picks up everything on the streets, in yards and open fields, and is almost always of a pollutional nature. It will contain oil, gasoline, rubber, fertilizer, and trash and debris of every conceivable nature. The volume of this storm water is massive and normally of short duration. For this



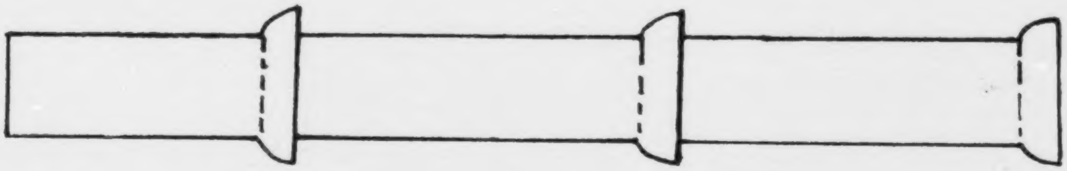
LIFT PUMP

reason, it receives no treatment. We now recognize the problems caused by storm water runoff, and research is under way to correct this very complicated problem.

Some cities have what is known as combined sewers, i.e., one system which collects both storm water and sanitary waste. These systems exist in older communities and create problems which are unacceptable by today's standards. When rain occurs, the treatment plant cannot adequately treat this enormous amount of water, and so everything goes untreated. While Texas has only a few miles of combined sewers in only three cities, many cities in the East have hundreds of miles of such systems.

A situation somewhat related to combined sewers does plague all sewer systems though, and that problem is storm water getting into the sanitary system through poor collection lines, mainly at joints.

A sewer line is constructed of short (usually 4') sections of pipe connected together -- like this:



If the joints are defective, water seeps in at the joints having come down through the soil above the line. This water is called infiltration and can amount to a fantastic volume. This infiltration has been measured at over 100,000 gallons per mile of pipe per day. To a line designed to handle the wastes from a few hundred homes, this amount of infiltration will completely fill the line, and then the waste from the houses has no place to go. When this occurs, manholes on these lines overflow, carrying untreated sewage into streams. The solution to the problem of infiltration is actually very simple from a technical standpoint. A better joint, available today, would reduce infiltration. However, in addition to the increased cost of this better joint, we must also realize that we have hundreds of thousands of miles of older pipes in the ground, and the replacement costs would be unbearably large. Certainly though, new construction should be with the better joint material.

DOMESTIC SEWAGE TREATMENT:

Before discussing the techniques used to treat wastes, we must first have a basic understanding of bacteria. Bacteria will work on or utilize organic matter until this organic matter is rendered stable or chemically inactive. Sometimes these bacteria cause very offensive odors, but frequently organic matter can be stabilized -- or purified -- without odor. This is brought about by two classes of bacteria: aerobic (active when oxygen is present), and anaerobic (active when oxygen is absent). If some organic material is placed in a bottle and stoppered, the aerobic bacteria will use up the oxygen present and then become inactive. The anaerobic bacteria then start to work and emit very foul gasses. If the supply of oxygen can be maintained, the aerobic bacteria will break down this organic material and not give off odors. Sewage treatment plants use bacteria to stabilize the organic matter present in the sewage.

SEWAGE TREATMENT:

At the sewage treatment plant, the process of cleaning up the water proceeds by one of several processes. First, metal bar screens are used to catch bulky items, such as pieces of wood, cartons, limbs, etc. These are removed and either buried or burned. The sewage then has the grit and sand removed by passage through a long chamber where the velocity is slowed sufficiently to let inorganics settle out, but allow organics to pass on to the next phase, which is called primary settling.

Primary Settling:

Here the sewage remains for a sufficient period of time (at least two hours) to let the bulk of the suspended solids settle out. This material which settles is known as sludge, while the liquid which flows on for further treatment is know as primary effluent.

Trickling Filter:

The primary settling tank effluent is sprayed onto a trickling filter, which is a tank filled with large rocks. The sewage trickles down and is collected at the bottom of the filter. Here, for the first time in the treatment, bacteria are used for beneficial purposes. (In the "Second Reader", the role of bacteria will be more fully discussed.) The rocks serve as a home for the bacteria, and as the sewage passes over the rocks, the bacteria extract dissolved organic material. The word "filter" is inaccurate, since a filter action does not actually occur. The bacteria which live in the filter are aerobic, and must have oxygen to live. Therefore, the trickling filter is not normally submerged, and it must have vents to allow free circulation of air.

Final Settling:

From the trickling filter (which could better be called a biological contact bed), the sewage flows to another settling tank -- which removes more suspended solids. There is a more-or-less constant sloughing of the bacteria in the filter which accounts for much of the suspended solids at this point.

Chlorination:

From the final settling tank, the sewage flows to a chamber where chlorine is applied to kill off harmful bacteria, and then on to the river.

Digestion:

That sludge which was collected in the primary settling tank and in the final settling tank is pumped to a sludge digester, where anaerobic bacteria go to work. The digester is kept closed, and these gasses are collected and burned -- so that the odors are eliminated. After 20-30 days of digestion, the sludge has been reduced to a more-or-less stable material, which is then removed from the digester to sludge drying beds. These beds are lined with sand and gravel; the liquid from the sludge drains through and the dried sludge can then be removed. This dried sludge, when properly processed, is an excellent soil conditioner, and most major plants sell their sludge for this purpose.

Normally at the first of the treatment plant, but sometimes at the last -- the sewage volume must be measured. This is necessary to determine the contribution by residents, so that expansions can be planned, improvements made, and operation aimed in the right direction.

Activated Sludge:

Another form of treatment -- called Activated Sludge, is almost exactly like the trickling filter system except a different form of biological contact bed is used. Instead of the bacteria living in the cracks and crevices of the rocks, they live in the liquid phase of sludge. This liquid sludge is active with live bacteria, hence the name -- activated sludge. This active sludge settles in the final settling tank and some is pumped back to the biological contact area -- to supply plenty of active organisms. These are aerobic bacteria, and air is pumped into the biological contact area to keep the bacteria alive.

Imhoff Tank:

Another treatment technique which is nothing but a combination of a primary settling tank and a sludge digester is called the Imhoff tank. In this method, the sludge settles out going directly to the digester in a "two-story" arrangement.

Contact Stabilization:

One fairly recent innovation or modification of activated sludge is the contact stabilization process. This technique brings the raw sewage into intimate contact with air and active organisms for a relatively short period of time, then sedimentation is used to settle out the active mass. This particular technique results in a very good effluent, but does require an even higher degree of operation than do other processes.

Stabilization Pond:

One other process which must be mentioned is the stabilization pond. This is just what the name implies -- a pond in which the sewage is allowed -- through natural methods, to stabilize itself. After primary settling, the sewage flows into shallow ponds, where bacteria do essentially the same thing as is done in the trickling filter or the aeration chamber. The oxygen for the aerobic bacteria comes from another of nature's workers -- the group known as algae. In shallow ponds, where sunlight can penetrate, algae grow. They may be seen as the green color in ponds, lakes, and streams. In their growth process -- they release oxygen, which is then used to keep the bacteria alive so that they can work on the organic material.

INDUSTRIAL WASTE TREATMENT:

Treatment of industrial wastes cannot be classified as simply as was treatment of domestic waste. Industrial wastes vary widely and are so complex that many of them must be individually tested, and special treatment techniques and procedures devised. When you consider that a single petrochemical plant can have as many as 100 individual products, you can see that the waste will be of an extremely complex nature. Therefore, a wider range of treatment techniques is used to treat industrial wastes. The more common wastes and their treatment techniques will be discussed in the "Third Reader." Since all industry is highly competitive and cost is their single most important factor, industry is constantly striving to cut the cost of waste treatment. They are reluctant, and properly so, to spend large sums of money for treatment facilities which will not be adequate. Therefore, rather lengthy periods of study, test operation, and research precede construction for most industrial facilities.

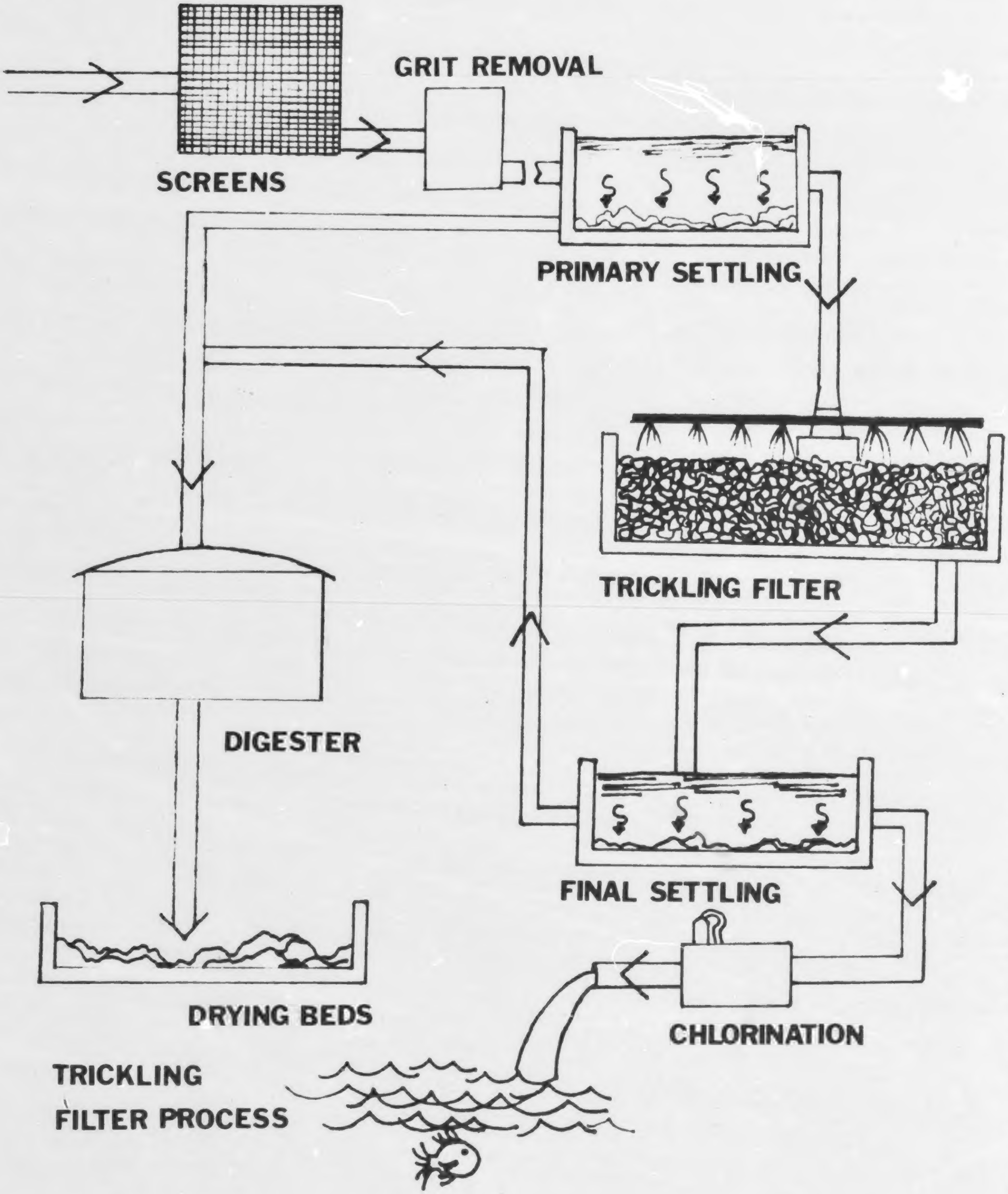
Frequently, industrial waste treatment facilities are very complex -- more so than municipal facilities -- because of the high degree of operational ability which the industry has available. It must be remembered that any industrial waste treatment cost must be passed ultimately to the consumer, since the cost of waste treatment to an industry is not helped along by taxes, nor can a charge be levied against the individual user.

OPERATION:

Experience with sewage treatment plants has shown that a majority of poor effluents are caused by improper operation of the facilities. There are some instances where the facilities are inadequate, and then the plant operator can do little to produce an acceptable effluent. In the other cases, however, proper operation can turn a mediocre effluent into a good effluent. Do not confuse the term "improper operation" with "poor operation." Poor operation -- the case where the operator does not understand what to do -- rarely occurs. Improper operation -- where the operator does not have sufficient time because of other duties; or where the operator does not have sufficient materials; or where the operator does not have an incentive for doing a proper job occurs more frequently. All improper operation has one prime cause -- the owner's lack of responsibility. If the owner does not accept his responsibility in the field of water quality control -- and make time, tools, and incentive available to his operator -- then improper operation and a resultant unsatisfactory effluent will result.

One frequently overlooked necessity for proper operation is adequate testing and record keeping. Without testing, no true idea of the efficiency of the waste treatment plant is possible, and records are always of extreme value, both for purposes of expansion and as a tool to determine the efficiency of treatment.

Historically, the operators of sewage treatment facilities have been underpaid, overworked, and the butt of degrading jokes. Today, however, the war against pollution is being fought at the sewage treatment plant, and the battle cannot be won with demoralized, ill-equipped, underpaid soldiers. The complexity of today's waste treatment processes and devices does require a degree of skill and sense of responsibility which must be appreciated and supported by the owner and the general public.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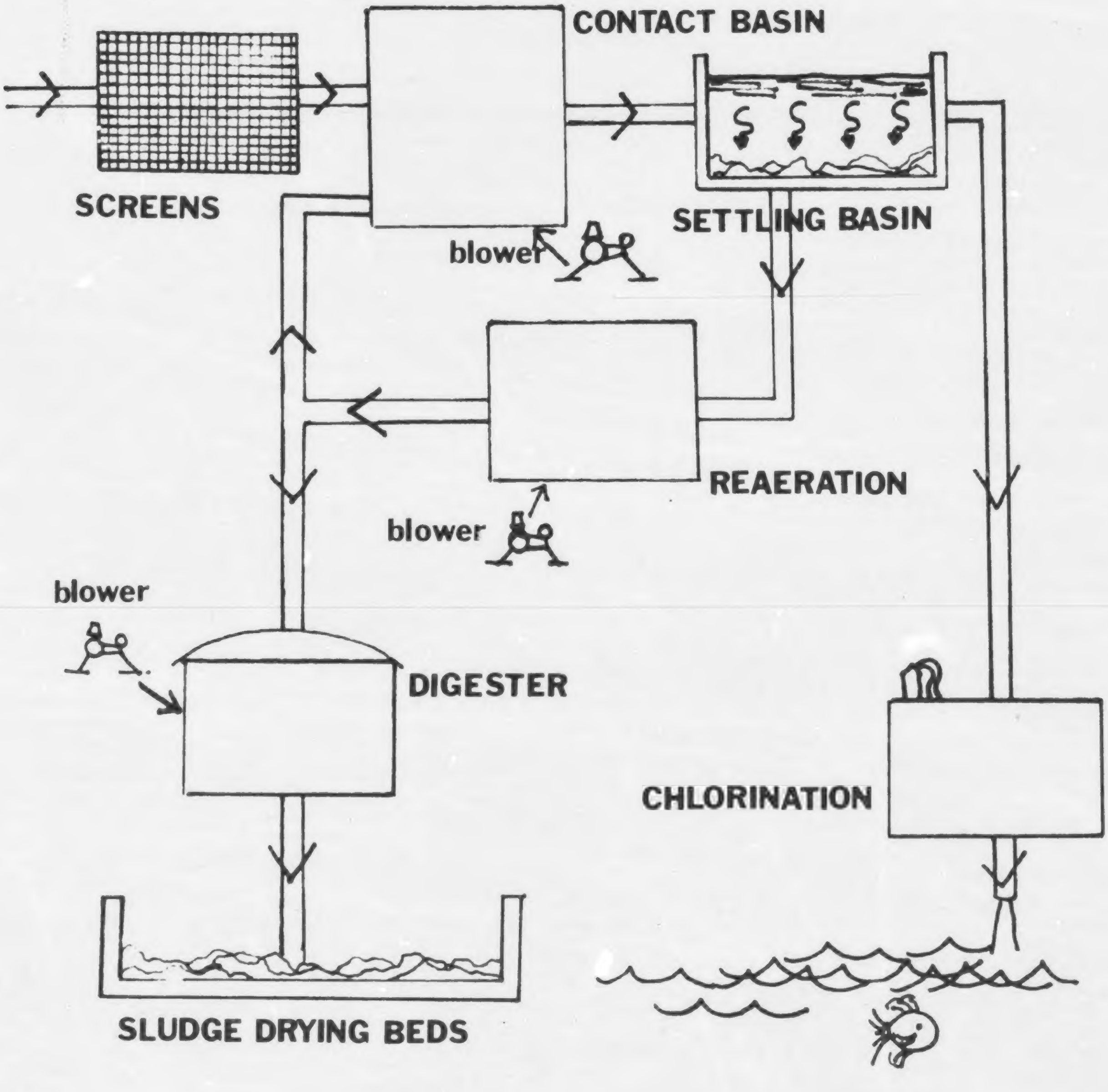
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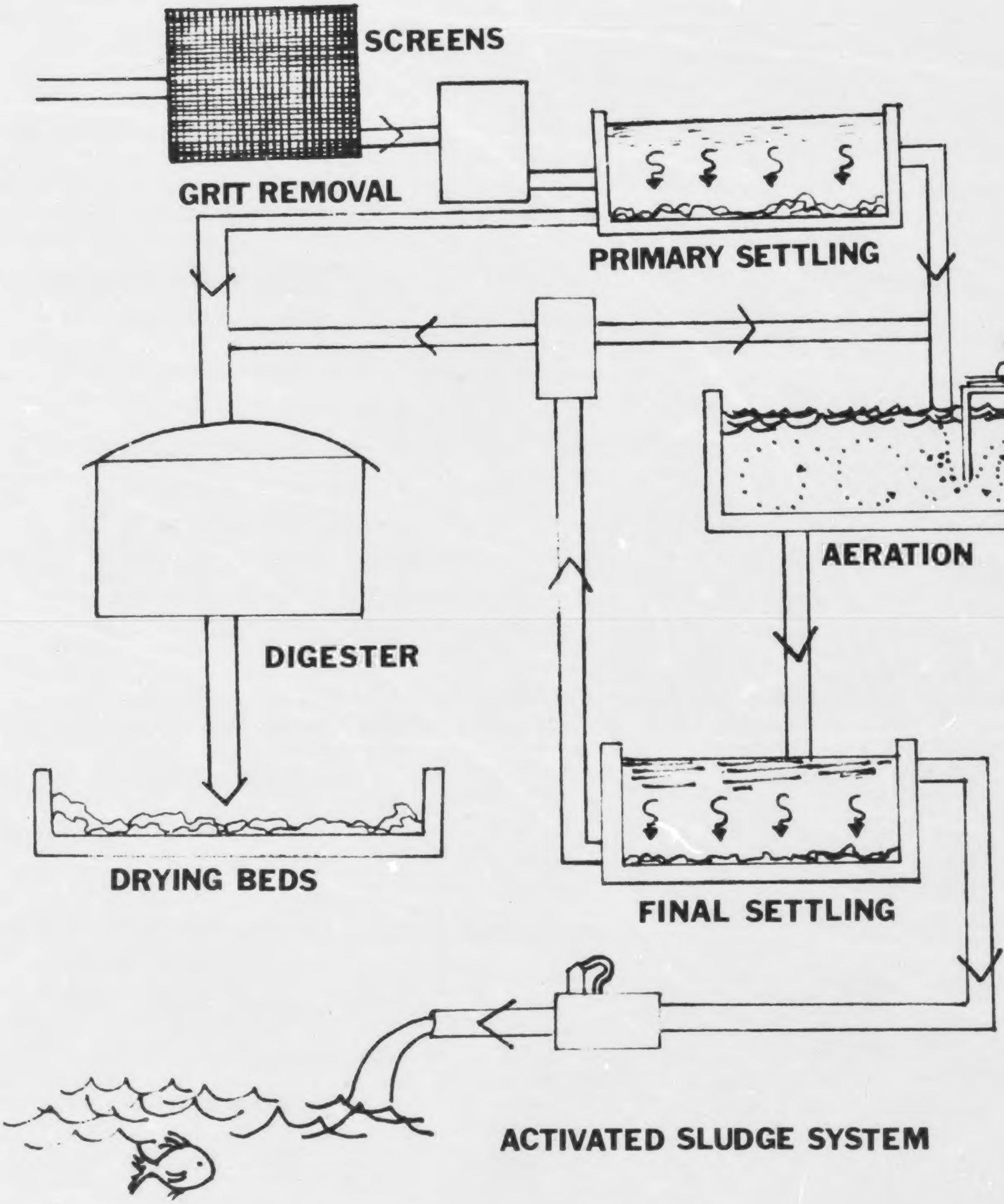
SCREENS
GRIT REMOVAL
PRIMARY SETTLING
AERATION
DIGESTER
DRYING BEDS
FINAL SETTLING

ACTIVATED SLUDGE SYSTEM

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CLEAN
WATER

SECOND READER ON WATER QUALITY

THE TEXAS WATER QUALITY BOARD AUSTIN, TEXAS

Agency Publication Number 70-04

SECOND READER ON WATER QUALITY

PREPARED
BY

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FOR THE

TEXAS WATER QUALITY BOARD

SEPTEMBER , 1970

SECOND READER ON WATER QUALITY

The First Reader discussed the basics of waste collection and treatment, with some small amount of discussion on the methods used for domestic and municipal waste treatment. Those sewage treatment plants which were described really do nothing more than a stream or river would eventually do. The stabilization of wastes in a sewage treatment plant is a man-made technique which follows very closely the things which occur in a stream. Man has compressed the stream action, both in time and space required. The stream action is called assimilation; and streams of different natures have different assimilative capacities. A fast-flowing stream will assimilate wastes discharged into it quicker than will a slow, sluggish stream. While it is true that a flowing stream improves its quality as it flows, it is not true that it becomes pure, since pure water means water with absolutely nothing in it except water. This quality improvement takes place because of the action of bacteria, algae, plants, and the addition of oxygen to the stream. This will be discussed in the section on BOD in this reader.

This reader will take up two basic items: measurement and eutrophication.

Any discussion of measuring will necessarily need to be preceded by a rather careful understanding of the units of measurement to be used. In the wastewater field only one basic unit is used, and it is relatively simple. The wastewater unit is milligrams per liter. An interchangeable unit, which is also commonly used, is parts per million. One milligram per liter is equivalent to one pound of salt -- or sugar -- or whatever, contained in one million pounds of water. Or one gallon of sugar -- or salt -- in one million gallons of water. This unit is used to describe the concentration of those various constituents in which we are interested. For example, sea water normally contains about 20,000 milligrams per liter, or parts per million, chlorides. Domestic drinking water would normally contain less than 200 milligrams per liter.

It would probably be helpful at this point to get some idea of the relative magnitude of a milligram per liter. You are probably familiar with the common petroleum barrel which contains 55 gallons. Four drops of any liquid added to this 55 gallons of water would result in a concentration equal to approximately one milligram per liter or one part per million.

Considerable attention is given to the matter of solids in water. These take two forms -- one being suspended solids, while the other is dissolved solids. Suspended solids can be likened to coffee grounds in water, while dissolved solids would be sugar dissolved in water. Suspended solids can be removed by the simple act of filtering, whereas dissolved solids cannot be filtered out. Natural waters will have varying amounts of dissolved solids, depending on the source of the water, and the terrain through which the water flows. As an example, exposed areas of salt in the upper portions of the Brazos River cause rather high dissolved solids levels, since water passing over this salt dissolves some of it away and carries it on downstream. Settleable solids are those materials which will settle to the bottom of a container when the liquid is allowed to sit still for a period of one hour. Because of the degree of treatment provided to waste material prior to discharge, little if any settleable matter should be present.

The most frequently used test for describing water quality is undoubtedly BOD. This is shorthand for Biochemical Oxygen Demand and is actually very simple, if taken in small, carefully understood parts. First, let's back into BOD by looking briefly at bacteria, protozoa, and similar such small living things. For added simplicity, let's group them all together, and call them bugs. We would then see that these bugs live much as you and I do -- by eating food and growing. We need air, or oxygen, to stay alive, and so does one group of these bugs. These bugs use organic material for food, and in a stream the bug will reach out and grab a piece of organic material, eat it, and in so doing, he would use a little oxygen from the stream. He has removed some organic material, and has used some oxygen in the process. The organic matter removed is converted to various end products, including carbon dioxide and oxygen.

If we now isolate a sample of water, with both organic material and oxygen present, we can measure how much oxygen the bug or bugs will use while they eat the organic material. This measurement is BOD. It is a measure of the amount of oxygen needed by the bugs while they eat organic material. Using known amounts of liquid and oxygen, and maintaining a semblance of actual stream conditions by controlling temperature and time, we can then make an evaluation of the organic material in sewage by measuring how much oxygen will be required by the bugs as they are eating that organic material.

BOD is expressed in milligrams per liter, and ranges widely. Naturally, BOD is considered as food for bugs, and needs to be present to some extent in all bodies of water so that fish and other living animals can have food. Excessively high levels, though, require so much oxygen that the stream is robbed of oxygen, and then our oxygen dependent bugs can't eat, can't grow, can't live. Raw domestic sewage has a BOD of about 250 to 300 milligrams per liter, and some industrial wastes range into BOD values of several thousand, with blood having a BOD of about 100,000 milligrams per liter. A well treated municipal sewage will have a BOD of 20 milligrams per liter or less. Streams in their natural condition will have BOD values up to 5 milligrams per liter, and streams fed by swamps frequently have BOD values in excess of 20 milligrams per liter.

Dissolved oxygen is a test used to measure the amount of oxygen present in water. Since dissolved oxygen in a stream is necessary for fish to live, the maintenance of dissolved levels above 4.0 milligrams per liter is essential. Oxygen is absorbed into water from the atmosphere, and a healthy stream will normally show dissolved oxygen levels from 4 to 10 milligrams per liter. However, excessive levels of organic material will cause the dissolved oxygen to be used up, sometimes at a faster rate than that at which it can be replaced. Absorption from the atmosphere is not the only source of oxygen for a stream, though, since algae and other green plants produce oxygen by photosynthesis. The ability to produce oxygen is dependent on the presence of sunlight, and for this reason streams which are heavily colored do not display the same ability to produce oxygen as would other bodies of water which are clear, and which are thereby more easily penetrated by sunlight.

pH is a term used to express the acid or alkaline condition of a liquid. If you consider the pH range as analogous to a 14 inch ruler, with a balance or pivot point located at the center, or at 7, then low values, that is, 0 to 7 values, will be acid, and 7 to 14 values will be alkaline. The farther from the balance point, or 7, the more intense the condition. pH is useful in many instances in determining the presence of industrial wastes. Low, or acid pH conditions cause corrosion to be more severe, and values which vary on either side of neutral frequently increase toxic conditions greatly. For purposes of comparison, lemon juice has a pH value of about 1.5, egg white has a pH value of 8.0, and milk of magnesia has a pH value of 10.

As has been previously discussed, bacteria or bugs are present in all natural surface waters, and in many underground waters. The best way to find out how many of these bacteria are present would be to count each one in a certain amount of water. Since this can't be done, because of the very small size of the bacteria, we use a test which is based on a statistical table, and measures more than just the type bacteria with which we are concerned. Of primary concern is the coliform bacteria, which originates from the intestines of warm-blooded animals. This test also measures a group of bacteria known as Aerobacter aerogenes, which grow in soil. The MPN test measures both the coliform bacteria and the soil bacteria, and the results are expressed as the number of bacteria found in a 100 milliliter sample of water. These values give us an excellent idea of bacteriological populations, even though some bacteria are not counted. Some comparative values of MPN levels show untreated domestic sewage with 20 to 40 million, and well treated sewage with 10 million or less. If this well treated sewage is chlorinated, the MPN values drop to around 5,000. Clean streams devoid of any waste material will have bacteria present, but the levels will be low.

EUTROPHICATION

The subject of eutrophication has been widely discussed recently and can be simply described as the aging process of surface waters, such as a lake, in which the waters are enriched or fertilized by natural and waste-borne nutrients which stimulate the excessive or nuisance growth of algae and aquatic weeds.

Natural eutrophication of a lake proceeds at a rate relative to a number of environmental factors, including light, temperature, pH, dissolved oxygen, alkalinity, and, of course, nutrients. This phenomenon occurs in all lakes with adequate nutrients to produce and support aquatic plant life. Solids and plant remains settle to the bottom, continually filling the lake from the bottom upward. Over a period of years, depending on the rate of eutrophication, the lake will become shallow, eventually transforming into a swamp or marsh, then a bog, and at last solid ground. The addition of nutrients, as from treated sewage, greatly speeds up this process by stimulating the growth of algae and rooted aquatic plants.

It should be understood, however, that eutrophic conditions do not necessarily mean that the water is unfit from a public health standpoint. A lake that receives high concentrations of organic waste and nutrients may be "green pea soup" in appearance due to a heavy algae population and yet be relatively as safe as other natural waters. Another beautiful, clear, blue lake may be much more aesthetic to the eye and yet be teeming with pathogenic (disease producing) organisms. Obviously, the most desirable condition is beautiful water that is free of pathogenic organisms and nuisance conditions.

The type of lake in question also determines the type and extent of eutrophication that can occur. As for example, reservoirs have a relatively fast flow-through rate. Consequently, to support significant algal blooms, a continuous source of nutrients is usually necessary to maintain nuisance conditions. Lakes with no outlets (Playa Lakes) however, tend to concentrate the nutrients that enter the lake by evaporation. It would be reasonable to assume that this type of lake could support and maintain excessive algal growths for an extended period of time. Natural lakes formed by natural phenomena would tend to fall somewhere between these two extremes.

It has been mentioned that possibly dredging could be utilized to keep certain lakes deep enough for the proposed recreational uses; however, there are problems that develop long before a body of water becomes so shallow that dredging would be necessary. During the latter stages of advanced eutrophication, odors may develop due to decomposition of the concentrated algae population and to the production of foul smelling hydrogen sulfide (H_2S) gas. This can result in a serious economic loss of lake shore property values as well as reduction in the recreational uses of the lake. The prolific growth of rooted aquatic plants in shallow areas can make boating and fishing difficult. Slime growths of offensive attached blue-green algae discourage swimming and may foul boat hulls. Dissolved oxygen may be completely depleted during certain periods, and this would eliminate the lake as an important sport or commercial fishing area. The dredging operation mentioned previously would also be detrimental to the ecology of the lake by covering and destroying the natural food and nests of important fish species.

In ecological terms, phosphorus is considered to be the most important nutrient responsible for eutrophication of surface water, especially lakes. Phosphorus is known to occur in several forms, that of most significance being soluble phosphate phosphorus.

Numerous authorities report that the mean total phosphorus content of most freshwater lakes is normally low, averaging around 0.01 to 0.03 mg/l, while the soluble phosphate content is but a fraction of this total. Since it is originally present in such low quantities, a significant increase in aquatic rooted plants and algae will deplete the phosphate to a point where it becomes a limiting factor. It has been demonstrated that lakes can assimilate soluble phosphate concentrations as high as 0.2 mg/l without excessive algae growths. The phosphate content in estuaries can be expected to be slightly higher than that in freshwater lakes; however, the average soluble phosphate content of some Texas estuaries is presently over 2.0 mg/l or about 10 times greater than the tolerable level reported above. The phosphates which are currently believed to be the cause of the accelerated eutrophication come from many sources, including fertilizer, human and industrial wastes, natural run-off and detergents. Large amounts of phosphates do come from detergents. In detergents, phosphates serve as a water-softening agent, and keep dirt particles suspended in water.

The principal methods of controlling nutrient concentrations in lakes have been: 1) Removal of the nutrients from their source, 2) Diversion of nutrient-rich waters from the receiving bodies, and 3) Dilution of these elements in lakes by controlled addition of water low in nutrients. Once the primary source of this fertilizing material has been controlled, the aging process will continue, since some nutrients will be delivered by surface runoff and from other uncontrolled sources; however, the eutrophication process will be slowed to more natural conditions.

TO HELP YOU BETTER UNDERSTAND THE PROBLEMS OF WATER POLLUTION CONTROL, WE HAVE COMPILED THIS GLOSSARY OF THE MOST COMMONLY USED TERMS IN WASTEWATER TREATMENT

Activated Sludge—Sludge withdrawn from the secondary clarifier in the activated sludge process, consisting of micro-organisms, nonliving organic matter and onorganic materials.

Activated Sludge Process—A biological process used as secondary treatment of sewage utilizing aerobic bacteria. Effluent from the primary clarifier is mixed with biological solids forming mixed liquor. This mixed liquor is aerated to promote biological growth breaking down the organic matter in the sewage. The aeration step is followed by secondary clarification. Sludge taken from the clarifier is returned to be used as the biological solids. The solids provide a culture or seed for the aeration tank.

Adsorption—An advanced way of treating wastes in which carbon removes organic matter not responsive to clarification or biological treatment.

Aeration—The process or method of bringing about intimate contact between air and a liquid.

Aeration Tank—Serves as a chamber for injecting air into water.

Aerobic Bacteria—Bacteria which require free (elementary) oxygen for their growth.

Anaerobic Bacteria—Bacteria which grow in the absence of free oxygen and derive oxygen from breaking down complex substances.

B.O.D. or Biochemical Oxygen Demand—An index of the amount of oxygen required for the biological oxidation of the organic matter in a liquid.

Chlorination—The application of chlorine to water, sewage, or industrial wastes, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

Coagulation—The agglomeration of colloidal or suspended matter brought about by the addition of some chemical to the liquid, by contact, or by other means.

Coliform Organisms—A group of bacteria recognized as indicators of fecal pollution. (See also escherichia coliform.)

Combined Sewer—Carries both sanitary sewage and storm water run-off.

Comminutor—A device for the catching and shredding of heavy solid matter in the primary stage of waste treatment.

Diffused Air—Method of aeration.

Digestion—The biochemical decomposition of organic matter which results in the formation of mineral and simpler organic compounds.

Dissolved Air Flotation—Method of removing oil and suspended solids.

Dissolved Solids—Solids physically suspended in sewage which cannot be removed by proper laboratory filtering.

Distillation—Process in waste treatment consisting of heating the effluent and then removing the vapor or steam. When the steam is returned to a liquid it is almost pure water. The pollutants remain in the concentrated resudue.

Effluent—The liquid that comes out of a treatment plant after completion of any treatment process.

Electrodialysis—A process by which electricity attracts or draws the mineral salts from sewage.

Escherichia Col.—A species of bacteria found in large numbers in the intestinal tract of warm blooded animals.

Floc—The agglomeration of smaller particles in a gelatinous mass having the feature of being more easily removed from the liquid than the individual small particles.

Flocculation—The coming together or coalescing of minute particles in a liquid.

Grit—Heavy, inorganic matter, such as sand or pebbles.

Incineration—The process of burning the sludge to remove the water and reduce the remaining residues to a safe, non-burnable ash. The ash can then be disposed of safely on land, in some waters, or into caves or other underground locations.

Inorganic Material—Material which will not respond to biological action (sand, cinders, stone). Non-volatile traction of solids.

Infection—Introduction or presence of pathogenic organisms in potable water supply. This is determined in two ways:

1. Bacterial Count—Number of bacteria developed under controlled conditions after 24 hours incubation period. In unpolluted waters count is frequently less than 10 per milliliter.
2. Coliform Index—Escherichia coli is organism normally found in intestinal tract of man and animals but rare elsewhere. Indicators of this organism family most reliable as index of pollution, purification efficiency and potability of water.

Interceptor—Interceptor sewers in a combined system control the flow of the sewage to the treatment plant. In a storm, they allow some of the sewage to flow directly into a receiving stream. This protects the treatment plant from being overloaded in case of a sudden surge of water into the sewers. Interceptors are also used in separate sanitation systems to collect the flows from main and trunk sewers and carry them to the points of treatment.

Ion—An electrically charged atom or group of atoms which can be drawn from waste water during the electrodialysis process.

Lateral—Lateral sewers are the pipes that run under the streets of a city and into which empty the sewers from homes or businesses.

Lagoons—Scientifically constructed ponds in which sunlight, algae, and oxygen interact to restore water to a quality equal to effluent from a secondary treatment plant.

Mechanical Aeration—Method of aeration.

Micro-Organisms—Microscopic plants and animals such as bacteria, molds, protozoa, algae, and small metazoa.

Mixed Liquor—The combination of primary effluent and active biological solids (return sludge) in the activated sludge process that is fed into the aeration tank.

Mixed Media Gravity Filter—A filter using more than one filtering media (such as coal and sand).

Nutrient—Any substance assimilated by organisms which promotes growth and replacement of cellular constituents.

Organic Matter—The waste from homes or industry of plant or animal origin. Volatile fraction of solids.

Organic Material—Material that can be broken down by bacteria (fats, meats, plant life).

Oxidation—The conversion of organic material to a more stable form using bacteria, chemicals or oxygen.

Oxidation Ponds or Lagoons—Holding ponds designed to allow the decomposition of organic wastes by aerobic or anaerobic means.

pH Value—A convenient method of expressing small differences in the acidity or alkalinity of solutions. Neutrality=pH 7.0; lower values indicate increasing acidity; higher values indicate increasing alkalinity.

Pollution—A general term signifying the introduction into water of micro-organisms, chemicals, wastes or sewage which renders the water unfit for its intended use.

Potable—Water fit for human consumption.

Polyelectrolytes—Synthetic chemicals used as a coagulant aid.

Primary Treatment—The first step in the sewage treatment process, aimed at removing inorganic matter and as much organic matter as possible. This phase generally consists of screening, grit removal and clarification.

Receiving Waters—Rivers, lakes, oceans or other water courses that receive treated or untreated wastewaters.

Salts—The minerals that water picks up as it passes through the air, over and under the ground, and through household and industrial uses.

Sand Filter—This removes the organic wastes from sewage. The wastewater is trickled over the bed of sand. Air and bacteria decompose the wastes filtering through the sand. The clean water flows out through drains in the bottom of the bed. The sludge accumulating at the surface must be removed from the bed periodically.

Sanitary Sewers—In a separate system, sanitary sewers are pipes in a city that carry only domestic wastewater. The storm water runoff is taken care of by a separate system of pipes.

Secondary Treatment—The second phase, or biological phase, of sewage treatment designed to remove organic matter. (See also "activated sludge process" and "trickling filter.")

Sedimentation Tanks—Provide a period of quiescense during which suspended waste material settles to the bottom of the tank and is scraped into a hopper and pumped out for disposal. During this period floatable solids (fats, oils) rise to the surface of the tank and are skimmed off into scum pipes for disposal.

Septic Tanks—Used to treat domestic wastes. The underground tanks receive the wastewater directly from the home. The bacteria in the sewage decomposes the organic waste and the sludge settles on the bottom of the tank. The effluent flows out of the tank into the ground through drains. The sludge is pumped out of the tanks, usually by commercial firms, at regular intervals.

Sewage—Largely the water supply of a community after it has been fouled by various uses. From the standpoint of source, it may be a combination of the liquid or water-carried wastes from residences, business buildings, and institutions, together with those from industrial establishments, and with such ground water, surface water, and storm water as may be present.

Sewers—A system of pipes used for collecting domestic and industrial waste, as well as storm water run-off. Lateral sewers connect homes and industries to trunk sewers, which channel waste into interceptor sewers for delivery to sewage treatment plant. Sanitary sewers carry only domestic and industrial wastewater. Storm sewers carry only storm water run-off. Combined sewers carry both.

Sludge—The accumulated suspended solids in sewage which can be removed by proper laboratory filtering.

Tertiary Treatment—The third phase of sewage treatment where nutrients are removed or additional clarity is achieved.

Total Solids—The total amount of solids in solution and suspension.

Trickling Filter—An aerobic biological process used as secondary treatment of sewage. Effluent from the primary clarifier is distributed over a bed of rocks. As the liquid trickles over the rocks, a biological growth on the rocks breaks down the organic matter in the sewage. The effluent is then taken to a clarifier to remove biological matter coming from the filter.

Turbidity—Any finely divided, insoluble impurities that mar the clarity of the water.

Waste Activated Sludge—That portion of sludge from the secondary clarifier in the activated sludge process that is wasted to avoid a buildup of solids in the system.

Waste Treatment Plant—A series of tanks, screens filters, and other processes by which most pollutants are removed from water.

GLOSSARY ON WATER POLLUTION CONTROL EQUIPMENT COMPONENTS

Primary Treatment

1. A system of lateral, trunk, and interceptor sewers collects and delivers municipal and industrial wastes to the treatment plant.

2. A mechanically cleaned bar screen filters out large pieces of debris, such as shoes, sticks, rags, and bottles. Material collected on the bars of the screen is combed off by a series of rakes. The screenings are disposed of as solid waste.

3. A grit collector is simply a basin in which the wastewater flow is slowed sufficiently to allow heavy inorganic solids, such as sand, gravel, and broken glass to settle out. A scraper mechanism removes the settled material for disposal as landfill.

4. Larger basins or a series of larger basins provide a greater reduction in flow velocity. In these basins, heavier organic particles settle to the bottom and lighter solid materials, such as oil, fats, and greases float to the surface. A scraper mechanism removes this material, now called sludge, from the bottom of the tank for pumping to a sludge concentration unit. Wooden flights skim the top of the basin and remove the floated material to a scum pipe for disposal. The water which flows from the primary settling basins is generally treated with chlorine to kill harmful bacteria and is then released to a stream, river or lake.

5. Primary treatment removes between 45 and 55% of the suspended solid material present in the waste flow and 35 to 45% of the biochemical oxygen demand.

Secondary Treatment

Secondary treatment is employed in conjunction with primary treatment Two methods are commonly in use.

1. Trickling Filter

   a. Following primary treatment, the flow is pumped into a rotary distributor. This unit resembles a large sprinkler, which trickles water over a bed of rocks from 6 to 10 feet thick. These small stones become covered with bacteria, which consume the organic material present in the wastewater. Depending on the amount of wastewater to be processed, the flow over the trickling filter may be recycled.

   b. A final settling basin, generally called the clarifier, receives the wastewater flow from the trickling filter. In this basin, the solid material present in the water is allowed to settle to the bottom of the tank. The sludge from this clarifier is pumped to a thickening unit for concentration.

   c. Chlorination of the water coming from the clarifier is all that is needed before it is discharged into a river or stream.

The trickling filter method is efficient, but limited by cold weather and space. Large volumes in all seasons are better handled as follows:

2. Activated Sludge Process

   a. Wastewater flows into a series of aeration basins. A bacterial culture is maintained in these basins. The bacteria need oxygen to live as they consume the organic material present in the wastewater, so air is forced into the water through sets of perforated pipes called diffusers.

   b. Final settling of the treated water is much like that from the trickling filter, except that a portion of the bacteria-laden sludge, is returned to the aeration basins to maintain the bacteria culture at a specified level.

   c. Chlorination, again, follows prior to release of the effluent into a river, stream or lake.

A combination of Primary and Secondary Treatment can remove 90 to 95% of the suspended solid material present in the wastewater and 80 to 85% of the biochemical oxygen demand.

Sludge Handling and Disposal

1. Sludge and scum are concentrated in a thickening tank by settling process. The thinner liquids are returned to the flow moving through the primary settling basin. The thickened sludge and scum is passed into a digester or cover tank where bacteria act upon the organic materials and reduce them to a more stable form. This process may be relatively simple, or more complex, perhaps employing the types of digesters using aerobic and anaerobic digesters. Gas generated in this process is used in heaters to maintain a favorable temperature balance in the digesters. Auxiliary heating equipment or gas-burning engines may also be powered by digester gas.

2. Following the digestion period, two weeks or more, the digested sludge is washed or elutriated to reduce its alkalinity. The sludge is then chemically treated for filtration.

3. A vacuum filter is no more than a large rotating drum, around which a porous belt of cloth or metallic mesh is strung. The lower part of the drum is immersed in the sludge and when a vacuum is produced in the drum, a layer of sludge is picked up. Suction draws off enough water to thicken the sludge to the consistency of wet cardboard. The filtered sludge can then be trucked off for incineration, landfill or processing into a low-grade fertilizer. Liquids from the vacuum filter return to the flow prior to the primary settling basin.

HOW TO INTERPRET WATER PARAMETER DATA

Care should be exercised to be sure that the data were collected from a representative sample. Following are a series of tables which should aid in the interpretation of data. The information contained in them is not absolute; it should be used only as a guide.

Warning

> If the relationships do not seem to apply to your investigation, other factors (perhaps requiring equipment not available to you) may be involved. Rather than risk publicizing an unwarranted conclusion, seek the advice of a professional.
>
> Cross-check related observations in different tables.
>
> For example, if low DO is detected under chemical testing, check turbidity under physical observations and severe organic pollution under biological observations.
>
> The interpretation of phrases such as "great variety," "less variety," and "high coliform count" may pose a problem for beginners. Most states have developed water quality standards which will be helpful in the interpretation of bacterial and some chemical data. If professional macroinvertebrate data (or assistance) are not available to the beginning investigator, he will have to collect extensive data himself; then make his own interpretations.

Table 1 - Biological Observations

In Case of:	Look for or Expect:
1. Using Sequential Diversity Index (SDI)	
Great variety with few of each kind	Clean water
Less variety with great abundance	Overly enriched (Moderate organic pollution)
One or two kinds only, with very great abundance	Severe organic pollution

In Case of:	Look for or Expect:
2. The Qualitative Interpretation of Freshwater Macroinvertebrates	
May fly, caddis fly, and stone fly larvae, plus a considerable variety of other macroinvertebrates	Clean water
Pollution tolerant types predominate, although a few less tolerant or unknown forms may be present	Moderate organic pollution Suggestion: Confirm with coliform and other tests.
One or two pollution tolerant types only, often present in overwhelming abundance	Severe organic pollution Suggestion: Same as above.
No macroinvertebrates at all, little or no plant life	Toxic pollution Suggestion: Same as above.
3. Quantitative Interpretation of Freshwater Invertebrates from Riffle Areas	
Note: Carefully review weather records for the preceding few weeks. A severe flood could invalidate the following interpretations.	
0 - 2 grams per ft.^{2} (blotted live weight)	Unproductive, probably clean stream. Suggestion: Check for toxicity.
3 - 5 grams per ft.^{2}	Normally productive. Probably well balanced stream community.
Over 6 grams per ft.^{2}	A. Highly productive stream, probably organically enriched (polluted).

In Case of:	Look for or Expect:
	B. Note: These relative values will differ in different parts of the country. C. Check the SDI.
4. Productivity Measurements	
Water at sampling site seems to be unproductive or overproductive.	Suggestion: Measure plankton productivity using standing crop, oxygen, pH, or carbon-14 method (or combination).
5. Fish Behavior	
Many fish observed to be "topping" (gulping air and/or splashing on surface)	Suggestion: 1. Check DO, IDOD, and BOD. 2. Check for toxic or oxygen demanding chemicals. 3. Determine organic content of water and bottom debris and/or sediments. 4. Check temperature.

Table 2 - Bacteriological Observations

In Case of:	Look for or Expect:
High coliform count	A. Raw or unchlorinated sewage discharge. B. Pasture or feed lot drainage. C. Storm sewer drainage immediately after a rain storm.

In Case of:	Look for or Expect:
Low coliform count	A. Clean water. B. Heavily chlorinated sewage effluent. C. Toxic discharge as from pharmaceutical company manufacturing antibiotics, or toxic chemicals. D. Other source of toxicity such as acid mine drainage.

Table 3 - Chemical Observations

In Case of:	Look for or Expect:
High DO's (12-30 mg/l) during daylight hours (supersaturation)	A. High biological productivity, especially producers (plants). B. Relatively quiet waters. C. Chemical interference in oxygen determination. Suggestion: 1. Check DO between 2 and 3 a.m. 2. Check DO at 1 or 2 hour intervals around the clock and graph results. 3. Search for source of excessive fertility. 4. Examine bottom muds for black anaerobic foul smelling (H_2S)

In Case of:	Look for or Expect:
	deposits that are overgrown by plants. 5. Compare DO above and below a dam or rapids area. Deaeration may be detected.
Low DO's (0-4 mg/l) during daylight hours	A. High organic content, both dissolved and suspended solids. B. High total bacteria and fungus count. C. If clear water, look for anaerobic spring (groundwater). D. Chemical interference in oxygen determination. E. Note water temperature. Suggestion: 1. Check for coliform bacteria. 2. See "Physical, Low Velocity" (Suggestion #1).
Toxic chemicals in general	Reduced biological productivity may be selective or complete.
Toxic or smothering chemicals which sink to bottom	No living organisms on or in bottom materials, but overlying water may have rich plankton and/or nekton population.
Floating oil slick	A. Low DO near surface. B. Oil coated wharf pilings, floats, and shore.

In Case of:	Look for or Expect:
	C. Dead or dying oil soaked birds and aquatic mammals. D. Few or no living organisms on oil covered surfaces. If in an estuary or open ocean front shore, this includes the entire intertidal zone.
High pH (8-11), high alkalinity (200 or more), high hardness (300 or more)	A. High turbidity. B. High biological productivity. C. If low biological production, look for toxicity or biologically intolerable combination of chemicals. D. May be of natural origin.
Low pH (2-5)	A. Acid mine drainage or industrial discharge. B. Low biological productivity. C. Low turbidity.

Table 4 - Physical Observations

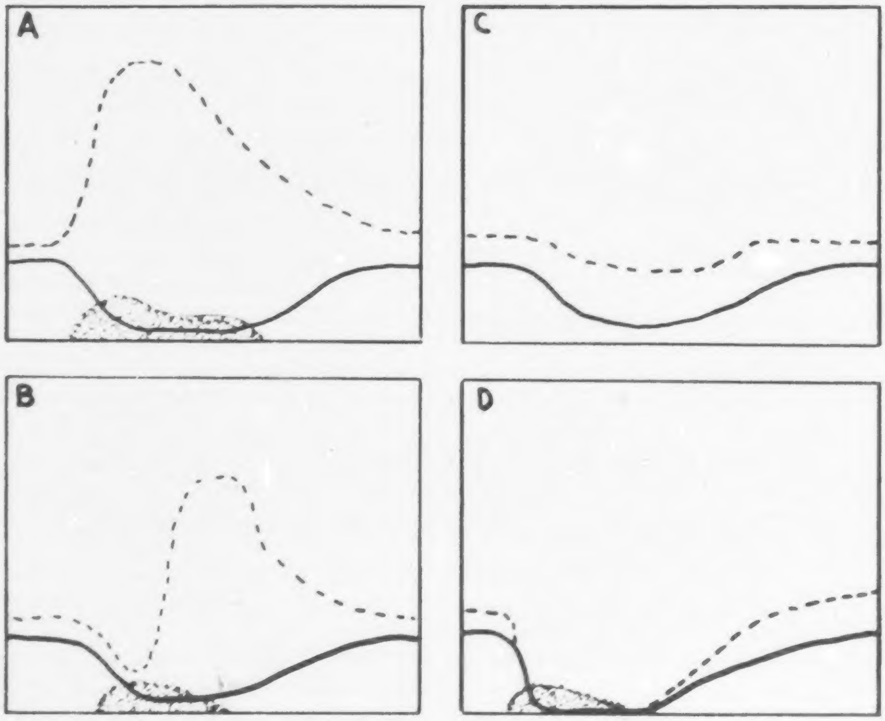
In Case of:	Look for or Expect:
High velocity and turbulence	A. DO approximately at saturation for temperature. B. Hard bottom, little sediment.

In Case of:	Look for or Expect:
	C. Biological organisms adapted to swift water.
	D. Particulate materials kept in suspension.
	E. Bank and bottom scouring (erosion).
Low velocity	A. DO may be above or below saturation.
	B. Coarse particulates may settle to bottom.
	C. Bottom may be soft.
	D. Organisms, if present, may be burrowers or may crawl freely on surface.
	Suggestions:
	1. If turbidity is high, see High Velocity, Item D.
	2. Check for kinds and amounts of plankton.
High volume of flow: normal, non-flood conditions (over 1,000 c.f.s.)	A. Note: This is probably a "big" river.
	B. These are difficult and expensive to study, even for professional groups.
	Suggestions:
	1. Examine the water for plankton.
	2. Place artificial substrates for both periphyton and macroinvertebrates.

In Case of:	Look for or Expect:
	3. Carry out chemical and physical analyses of water.
Flood conditions (any stream)	A. High coliforms count in first few hours, diminishing as time goes on.
	B. "Dumping" of waste holding ponds by industry.
	C. "By-passing" of sewage treatment plants.
	D. See also "physical" High Velocity, Item D, and Low Velocity, Item B.
Low volume of flow (up to 1,000 c.f.s.)	A. Note: Smaller streams from 0 up to 200 - 300 c.f.s. are generally most satisfactory for group studies but much depends on local circumstances, resources, and objectives.
	B. Most of the analyses described can be carried out on such a stream.
Heated water discharge (no chemical pollution assumed although heated discharges often contain chlorine or other chemicals used to kill biological growths in the plant.	A. Differences between the biota in or near the discharge canal or pipe and that in or around the intake.
	B. Artificial substrates may be used.
	Suggestions:
	1. Make the above comparison winter and summer, or even better, each season.

In Case of:	Look for or Expect:
	2. Chart the dispersal of the heated water on the receiving water at different times of the year, different wind directions, different tidal phases, etc. If available, use depth recording thermometer and in clude depth as well as surface temperature Graph your results.
Lakes, reservoirs, and estuaries	A. Thermal (or other density caused) stratification. B. Changes in water level, either natural or man made. Suggestions: 1. Practically every suggestion offered elsewhere for stream or river pollution studies can be applied to lakes, reservoirs, or estuaries, making due allowance for differences in the basic nature of the waters. 2. Stratification, seiches, density currents, tidal currents, and salinity are additional physical factors to be considered. 3. Biological procedures are virtually identical, but while DO is the same, most of the chemical methods cited apply to fresh-water only.

Benthos Responses to Pollution:



—— . Number of Kinds of Species

------ . Number of Organisms

▨ . Sludge Deposits

FOUR BASIC RESPONSES OF BENTHIC ANIMALS TO POLLUTION

A. Organic wastes eliminate the sensitive bottom animals and provide food in the form of sludges for the surviving tolerant forms.

B. Large quantities of decomposing organic wastes eliminate sensitive bottom animals and the excessive quantities of by-products of organic decomposition inhibit the tolerant forms; in time, with natural stream purification, water quality improves so that the tolerant forms can flourish, utilizing the sludges as food.

C. Toxic materials eliminate the sensitive bottom animals: sludge is absent and food is restricted to that naturally occurring in the stream, which limits the number of tolerant surviving forms. Very toxic materials may eliminate all organisms below a waste surface.

D. Organic sludges with toxic materials reduce the number of kinds by eliminating sensitive forms. Tolerant survivors do not utilize the organic sludges because the toxicity restricts their growth.

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Zones of Degradation and Recovery

The obvious place of disposal for the liquid wastes of a community is a natural body of water. This method is called disposal by dilution and has been used with more or less success by many cities. Streams and lakes are capable of assimilating certain levels of organic pollution without deleterious effects, but the increasing urban population and industrialization, accompanied by a lag in the construction of treatment systems for sewage and industrial wastes, has in many cases exceeded this natural assimilative capacity. In a normal stream there is a balance between animal and plant life. Pollution of a stream to an excessive amount, whether it be by sewage or industrial wastes, upsets the cycle. This excessive pollution usually places too much unstable organic matter in the stream to be naturally assimilated. This results in an over-abundance of certain organisms and diminishing existence of others. Farther down the stream, however, at a distance dependent upon the amount of pollution with relation to stream flow and stream conditions, and whether or not more pollution was added by another source, the normal cycle is re-established. This restoration is known as self-purification.

When excessive organic pollution occurs, fairly well defined zones of pollution and recovery can be noted. Each zone can be characterized by physical, chemical and biological conditions easily recognized by a trained observer or investigator. The zones are:

1. Zone of Degradation. This will be established just below the outfall of the pollution inlet and will result in a reduction of dissolved oxygen by about 40 percent. The water will become turbid and

dark, excluding sunlight. Decomposition of solid matters will occur. Besides a progressive reduction in dissolved oxygen, tests will indicate the presence of carbon dioxide and ammonia. Higher forms of life, particularly fish, will be killed or driven away. Fungi will be present and may form in white and grayish masses on submerged sticks. At the lower portion of this zone, fungi will give way to bacteria. Certain forms of bacteria and worms, typical of this area can be recognized under microscopic investigations (1) (6).

2. Zone of Active Decomposition. This zone, clearly marked in cases of heavy pollution, is characterized by the temporary absence of dissolved oxygen. Throughout the entire zone the oxygen level diminishes from 40 percent in the preceding zone to zero and rises again to 40 per cent. In this zone there is no fish life, the water will be grayish and darker than in the preceding zone, septic conditions have set in, and the organisms of active organic decomposition are at work. As a result of the decomposition there may be bubbles of escaping gas and masses of solids may come to the surface to form a black scum. Methane, hydrogen, nitrogen, hydrogen sulfide, carbon dioxide, ammonia and other odorous gases may be given off. The fungi will have mostly disappeared and the higher forms of life will be confined to slude worms, rat-tailed maggots, and other insect larvae such as mosquitoes. Where pollution is intensive and decomposition is extremely active, the transition to the next zone may be greatly delayed.

3. Zone of Recovery. As the amount of decomposition diminishes and the BOD is satisfied, improvement takes place and the water becomes

clearer. The oxygen content increases from 40 percent, aquatic life reappears, fungi will reappear to a limited extent, and blue-green and then green algae will reappear in this zone. Nitrites, nitrates, sulfates, and carbonates will increase with carbon dioxide and ammonia decreasing. The species of fish more tolerant of pollution such as the sucker, catfish, certain minnows, and carp will find food among the worms and insect larvae on the bottom.

4. "Clear-Water Zone." Here the stream will have resumed the appearance of natural waters. The usual plankton of clean waters will be present in large numbers and their presence will encourage a large fish population which will be the less tolerant type including game fish. The "oxygen balance" will have been attained with dissolved oxygen close to saturation.

If a large amount of pollution is dumped into the water or a number of pollution inlets are allowed along the body of water, the zones of recovery and clear water may never develop. The consequence of this situation is the death of that body of water.

Clear Water vs Pure Water

After mentioning all the visible indices for detecting pollution, it should be stated that all forms of pollution are not quite as obvious; clear water does not necessarily mean pure water. Acid mine drainage, cyanide, mercury, bacteria and viruses, although usually invisible to the naked eye are also serious pollution problems.

A. Acid Mine Drainage

Of the nation's major industrial water pollution problems, perhaps none is as complex as acid mine drainage. The chemical pollution and sedimentation it produces pose a severe threat to municipal and industrial water supplies. The streams that receive untreated mine drainage waters are generally declared useless for recreational activities. In 1967 the death of more than a million fish was attributed to mine drainage, ranking this type of pollution as one of the primary causes of fish kills in the United States. The primary pollutants found in coal mine drainage are chemical contaminants (acids, iron, sulfides, and other metals) and sediment. Acid formation and some sedimentation occur when the drainage patterns bring water into contact with sulphur bearing minerals in mines or refuse piles. When the acid combines with calium and magnesium to form sulfates, the mine water also becomes very hard. Sound water and soil management practices in mining areas can be effective in reducing the mine drainage problem. But, despite various preventive measures, a certain amount of drainage is inevitable from active mines and some form of treatment of the mine drainage will be required. A number of advanced waste treatment concepts, among them reverse osmosis, electrodialysis, ion exchange, distillation, and crystallization are under study for application to mine drainage.

B. Cyanide

Hydrocyanic acid or hydrogen cyanide and its salts, the cyanides, are important industrial chemicals. Unfortunately, they are also extremely poisonous to fish and other aquatic life when found in water. Fish can recover from short exposure at concentrations of 1 mg/l or less, but a long exposure and/or higher concentrations it will become fatal. Cyanide wastes are produced in metallurgical processes, especially electroplating. Reduction of spillage, draining of process pieces, prewashing, use of wash water to make up new solutions, and recovery of spent baths are measures of control. Extreme care must be taken in the treatment of cyanide wastes not to release hydrocyanic acid gas into the atmosphere. Methods now in use include acidification and aeration, chemical precipitation, and chlorination.

C. Mercury

Mercurial poisoning has also been a source of contamination to our contamination to our waters. The most significant case of this type of pollution was found in Japan. A severe neurological disorder resulted in the area of Minamata Bay as a result of eating fish and shellfish from these waters. Many species of animals including waterfowl were succumbing to the "disease" called Minamata disease. Clinical reports showed cerebellar ataxia, constriction of vision, and dysarithia. The disease was even found to have been passed on to babies born of mothers who had eaten the contaminated fish. All these symptoms were very similar to mercury poisoning. The cause of the poisoning was later found to be a local factory which discharged methyl mercury compounds from its processes to the water.

D. Bacteria and Viruses

Many types of bacteria can be found in water. Most of them are of no sanitary significance, some are indicators of pollution but are harmless, and others are pathogenic (disease forming). Pathogenic bacteria have been studied in great detail because of their importance to the survival of man. The most serious waterborne diseases are asiatic cholera and typhoid fever. Other human diseases known to be transmitted through water are paratyphoid fever, bacillary dysentery and amoebic dysentery. The treatment of bacteria-induced diseases is much simpler than that of viral diseases since the bacteria are more complex microorganisms and hence are more susceptible to damage. The The sulfa drugs and advent of antibiotics proved quite effective against most of the common pathogenic bacteria. Since the test for pathogens is very difficult and the number of pathogens to be found in water very small, coliforms are usually tested for and used as an indicator of pollution. Although non-pathogenic, coliforms are more closely related to the intestinal pathogens than any other group of bacteria. Their absence of presence can also be easily determined by routine laboratory investigations.

Viruses can be defined as a group of infectious agents which are smaller than ordinary bacteria and that require susceptible host cells for multiplication and activity. The viruses are almost pure chemical identities, nucleic acids, which make them difficult to control with chemical agents. The presence of the viruses which cause poliomyelitis, infectious hepatitis, coxsackie (a nonfatal throat disease) and gastroenteritis have been found in the presence of a host. They call upon the host to furnish all the necessary components for their cellular structure. The host is therefore robbed of key materials needed for its cellular development. As mentioned above, the chemical nature of viruses makes then difficult to control. The only effective method of combating viruses has been through the production of antibodies in the host cells. The purpose of these antibodies is to react with the virus to prevent their reporduction and ultimately acquire immunity. Chlorination of water, particularly when combined with other treatment, inactivates viruses although relatively heavy doses and long contact periods are necessary.

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The following materials are included as project suggestions. All were taken from A CURRICULUM ACTIVITIES GUIDE TO WATER POLLUTION AND ENVIRONMENTAL STUDIES: Activities Vol. 1.

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An Elementary Investigation of Local Water Anti-pollution Programs by interviewing Government Officials

I. Introduction

This activity could be used in classes for 6th through 12th grade students to evaluate the evident effectiveness of the government to deal with water pollution. The students should become aware of and develop an interest in the local problems of their communities.

II. Questions

1. Lead to the activity by asking what are the water pollution problems in our community.
2. Stir interest by asking:
   a. Who are the people responsible for controlling these problems?
   b. Do they use the authority given them effectively?
3. The teacher may evaluate the activity by considering:
   a. What were the students' results?
   b. What reasons were there for these results?
   c. Were the students' questions well prepared?
   d. Was the students' back-up knowledge sufficient?

III. Equipment

None is required.

IV. Procedure

1. Find out a few problems in your community by reading the newspaper.
2. Determine which laws pertain to these problems.
3. Make up an outline of questions.
4. Set up the interview.
5. Record the results and your reactions by writing articles or reports.

Anti-pollution Laws

I. Introduction

This activity is designed to determine what circumstances in a given area allow cases of obvious pollution to continue. While it is true that the time gap between creation and enforcement of laws is one of the primary causes, this is not always the case. If anti-pollution laws do exist, it may be that a gap also exists between what is considered to constitute pollution and what legally constitutes a case of pollution. In other words, both legal and illegal polluters have been found to exist.

In order to make such determinations, the students are required to wade through many legal documents as well as carry out interviews. Therefore this activity is suggested for senior high school students.

II. Questions

1. Lead to the activity by asking:
    a. Why isn't something being done about citing a local polluter?
    b. How can you determine the legal status of an industry?
2. To initiate the activity ask:
    a. What agencies (public and private) are directly concerned with industrial pollution in your river basin?
    b. Which ones make the regulations?
    c. What are they?
    d. What people should be contacted for information? Local? State? Federal?
    e. What questions do you want answered? For example, is there a water quality standard in your state?
3. To continue the activity ask:
    a. What types of testing have been done?
    b. Should you make tests of your own?

c. Who interprets the result of the testing?

d. What is the mechanism for reporting violations?

e. How do you survey local industry?

f. What steps are being taken toward sewage abatement?

g. Who is responsible for enforcement of water pollution regulations?

4. To evaluate the student consider:

   a. What types of background material did the student gather?

   b. Were the questions formulated in advance of personal contact with resource people?

   c. Was the plan of attack well planned and viable?

   d. Can the student differentiate between legal and illegal pollution practices?

   e. Is the student aware of public recourse that can be brought against the illegal industrial polluter and the steps in this process?

III Equipment

No special equipment is required unless the students do testing in the field.

IV. Procedure

1. Select a site of obvious water pollution.

2. Determine the industrial or private persons who are contributing to the pollution.

3. Investigate the local, state, and federal agencies concerned with pollution in your area and determine what laws are now in existence.

4. Select one specific industrial polluter and secure background material on the corporation, i.e.,

   a. How is it polluting and to what degree (may be necessary to perform tests)?

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   b. When did it begin?

   c. How many people are employed?

   d. What are its gross earnings?

   e. What responsibility does it feel it has?

5. If a violation is occuring, discuss the courses of action regarding it. You may want to do one of the following:

   a. Go to the corporation's management and ask about the responsibility to meet legal standards, past actions, and projected activities.

   b. Go to the local politicians about the specific corporation.

   c. Go to the relevant enforcement agencies with your data and attempt to find out what they are doing.

V. Limitations

You may have difficulty arranging interviews. Some people are reluctant to talk freely about the situation. This often includes politicians, factory managers, and heads of agencies on all levels.

Conflicting evidence may occur in the data collected by personal interviews. Biases and backgrounds of the persons being interviewed should be taken into account.

Interpretations of the law may be a problem at times even for the "experts"

If violations are found and reported, don't expect instant action. Legal mechanisms often take a great deal of time.

How to Win Friends from Skeptics, Critics, and Doubtful School Administrators Without Really Trying

I. Introduction

This activity is designed to get students involved in a campaign to elicit interest, help, and support from people in a school system (chiefly administrators) who may not be in sympathy or agreement with the focus on an environmental approach to education. These activities are intended to demonstrate that the cost and public relations aspect may serve to enhance such a program rather than hinder its development.

II. Questions

1. Pose the following questions to the students to initiate or lead into a discussion relating to problems in those schools where a gulf exists between students, teachers, and administrators regarding the implementation of a viable environmental program.

   a. How might a small group of students communicate effectively with their principal, headmaster or similar administrator?

   b. What problems seem to underlie the difficulty (cost, public relations, scheduling)?

   c. What angle of consideration of this particular aspect cited would be most effective in dealing with the specific problem?

   d. How do you think that student action might help solve the problem and what limitations do you anticipate?

III. Equipment

Materials for writing and illustrating should be available to the student as well as certain statistical data relevant to environmental education, books, and newsworthy articles which would assist the student in carrying out this type of activity.

IV. Procedure

The method for seeking assistance and support from school administrators will vary depending upon the inherent problems of that institution and the type of environmental program desired by that school. Those students interested in specific aspects of pollution should be encouraged to take an active role in this activity.

Several procedural approaches are described below. One or more of them may be used as indicated by the problem in the school, perhaps combinations of two or more procedures may be used, or procedures not developed here but devised by the group to fit the particular situation.

1. Use of existing clubs, organizations, or groups.

   Make a checklist of all the extracurricular clubs and organizations in your school and select those groups which would be used to promote the cause of environmental education. Here are a few suggestions.

   a. Art Clubs might be asked to sponsor a photography contest on pollution or pollution sculpture display in the school library. This would bring attention and interest.

   b. Science or Biology Club might be asked to form a splinter group called the Ecology Action Group which could actively campaign for the type of school program desired. They could distribute printed material on the merits of environmental education, generating further interest by use of bulletin board displays, posters, or conducting an all school assembly to "educate" all on the aims and goals of the specific program wanted at their school.

   c. Debating Clubs might devote an entire school term to debating issues related to the pollution problem. School Publications would ideally serve as an effective instrument to disseminate information and keep the community up to date on progress of the "campaign." A special column on Environment in the newspaper, various pictures of worthwhile and pertinent activities accomplished by the school's participants could add much to the overall support of such an endeavor.

2. Large Group Activity.

   a. There is no better way to impress people of the significance of a particular need than the large group activity to improve or call attention to something.

b. Those students most interested or skilled in matters of organization might like to coordinate an all campus or all school cleanup. This would require committees to handle such areas as publicity, manpower, collection, sites, and disposal.

c. A clean-up activity might be followed in a month or two by a beautification project undertaken by a smaller group or groups. The local newspaper could be called in to help the cause by a well-placed feature article employing several pictures.

3. Improvisation of Equipment.

Since the cost of any program is a main obstacle to overcome in the eyes of an administrator, those activities which show how experiments may be done at minimal expense are important. Students who are familiar with certain procedural techniques described in the guide should be asked to demonstrate how alternate methods may be used. Drawing from examples in the Bacteriology of Water section and the Hydrologic Cycle part, substitutions of more sophisticated equipment may be shown.

4. Public Relations.

a. Many schools are concerned about their public image. The probability of conflicts and the subsequent loss of prestige make many an administrator hesitant about the school's direction in a full-fledged program of environmental education.

b. Through the use of questionnaires, students may seek public information about certain issues relating to pollution. For example, sewage treatment in the school's area may be the topic for one questionnaire, or the district water supply may be another timely topic for polled opinion.

c. Radio programs and P.T.A. discussions by the students might be effective for large-scale communication. Involvement of parents, such as a car pool for necessary transportation, would bring in a very important interest group and, at the same time, create an awareness of the sincere effort by the students in achieving their goals.

d. A very successful method of arousing public interest is the local newspaper. Students who have had journalistic experience should be encouraged to write weekly articles and to document their news items with actual accounts of student activities which are concerned with the environmental crisis.

V. Limitations

1. Perhaps the greatest obstacle to be encountered in attempting to implement an environmental studies program is that of scheduling. Many schools are so regimented that it may be difficult for students and teachers to find the time needed for these activities. Since such a diversity of specific problems may arise here, it would be beyond the scope of this document to attempt a solution to all of them.

2. It may be possible to offer "time-trades" with other teachers. They may, for example, be much more willing to give up some of their lab or classtime in exchange for some of yours. It may be possible to convince athletic departments that an outside activity such as an all-school cleanup may be a worthy substitute for gym classes one day. Such tactics as these are only beginnings, but as enthusiasm grows among the students, faculty, and administration the possibilities are endless until finally the whole school may choose to revolve around an environmental theme.

3. One must also consider the possibility of alienating the local industrial polluters. This can be avoided by taking a positive rather than a negative approach to the pollution problem. It is better to ask, "How can we work together to alleviate the problem?" If tact is used, you may find that industry is as interested as you are in working toward a solution and may even contribute in helping solve problems. A strong word of caution might be given to those who are impulsive and impatient in their dealing with the public at large.

An Anti-pollution Club

I. Introduction

This activity is designed for high school students who are interested in starting a club dealing with different facets of pollution.

II. Questions

1. Lead to the activity by asking:
    - a. What problems of pollution in your area would you like to see remedied?
    - b. How could student action help resolve that solution?
2. Initiate the activity with questions such as:
    - a. What specific aspect of possible action would students be most interested in?
    - b. What type of student or school organization would be most effective and useful to enable students with their crusade?
    - c. What angle of consideration of this aspect would be most effective in dealing with the problem?
3. Continue the activity with:
    - a. Could an outside institution help the organization in any way?
    - b. Could increased publicity further spur or expand the program?
    - c. Have all of the facets (i.e., side effects, sources, relationship to the total pollution scope, consequences, etc.) been dealt with?
    - d. Are there any similar problems in the area?
    - e. Are there any other schools or organizations that might need help or could benefit from your organization's experiences?

4. Consider evaluating students with questions such as:

   a. What did your group accomplish?

   b. How did the results, conclusions, or experiences compare with those anticipated?

   c. How could the plan be improved?

III. Equipment

The equipment required will be determined by the activities of the club.

IV. Method

The method for starting an organization will vary depending on the school itself and the kind of program desired. Students interested in the numerous aspects of pollution (i.e., science, legislation, philosophy, etc.) should be encouraged to participate because differing skills are needed in any project. If the students show an interest in establishing a club or similar student organization, help them out by:

1. Finding out the procedures for establishing a club.

2. Defining the purpose of the club (write a charter).

3. Publicizing the club.

In defining purpose, the activities that the club hopes to carry out or the possible lines of action should be considered.

After the club has been functioning for a length of time, it might be advisable to sit down as a group and list or outline the activities the group has engaged in. This outline should include the failures as well as the successes. From this outline, a short explanatory program of what the club is doing could be evolved very easily.

The program could utilize any posters and/or charts and anything else that the club has produced to explain and exemplify pollution.

A 10 to 30-minute slide program with a narrator and sufficient subject matter can be very effective. It could be presented to students in other schools to encourage them to form their own club.

V. Club functions

1. Cleanup of polluted areas.

Organize a basic plan for the cleanup of community rivers, streams, and highways. Make use of volunteer community citizens. Review the sites to get an idea of how and what to clean up. Needed materials could include trash containers, vehicles for pick-up, and transportation. It is recommended that plastic or canvas bags be used for waste instead of paper bags.

2. Underground newspapers.

Underground newspapers are effective tools for the students to work with because they are not limited by the censorship of the administration. Organizing a paper that will be published regularly is a Herculean task. As the group starts work they have to raise money for supplies and decide on the purpose and format of the paper. Usually money can be obtained by soliciting students and organizations. Some problems are: interest has to be maintained; the paper has to eventually pay for itself; and the staff should be organized and committed.

3. Distribution centers (books).

As club activity, a booth can be set up and operated by the students to sell or distribute material concerning pollution. Buttons, posters, and stickers can be made by the students and sold for a profit. A number of "important" students can be selected to receive these materials free, in order to stimulate interest. Material which could be distributed could include pamphlets on water and other kinds of pollution which are free upon request from the Federal government; the Congressional Record which is informative; and school newspapers concerned with pollution subjects. This keeps a constantly changing pile of materials at the booth.

4. Erosion.

Find an erosion problem in your community that needs attention. Determine what would be involved to correct the problem. If it is a major undertaking, seek the help of the community. If it is a small project, gather the needed equipment and materials and set up a work day for the club and other interested students.

5. Colleges and Elementary Schools.

Contact colleges in the area to see how a cooperative (i.e., sharing data equipment, ideas, personnel) can evolve in an academic area. Contact elementary school teachers to see how your club activities can be shared with the younger students.

6. Communication.

Communication has an important role in any activity as it is necessary to make information public so that it can be an effective force in the school and community. The methods of communication available are unlimited. Inside the school, use the school newspaper or the distribution of dittoed sheets at information centers. Outside of the school the students could set up an underground newspaper and talk to the local radio stations and newspapers about time and space to discuss their activity.

7. Poster and Art Exhibits.

For any art exhibits, proper hanging space must be available. There are several exhibits made-up for exhibition in schools; one is available from Eastman Kodak Company. These exhibits are of photographs taken by students and judged by professionals, and rated 1st, 2nd, or 3rd. You can find out about these exhibits by asking the local Kodak shop; for other exhibits ask a local museum.

Poster contests can be sponsored in your school by the art or the science department. All you need to do is to arouse enough enthusiasm for the project so that you have enough contestants. One idea for promoting the enthusiasm is to make materials available to the students. Often, when some kind of prize is offered, more of the older students will participate. Otherwise, your best participants will be the students in the lower grades.

Having any kind of exhibit in the halls of a school building will help in bringing the students together. You will find a contest motivates some students who would not have been motivated otherwise.

8. Field Trips.

Field trips are interesting and useful to a club. But trips should be to areas of interest and have relevancy such as areas of established pollution. The date, time, and methods of transportation should be set up before the designated time. It is possible to get help or maybe permission from authorities if you write ahead of time or call to ask.

The purpose of the trip, either testing or knowledge-seeking, can be discussed beforehand to look for key points during the trip. In the case of testing water, legal complications should be taken into consideration.

Student Planning of a Pollution Assembly

I. Introduction

This activity is designed to motivate students to plan a slide show on their local pollution problems to be shown at a school assembly. Such an assembly might act as a springboard to further activities on a larger scale if it is successful in bringing an awareness of local conditions to the student body. An assembly of this kind can be planned and produced by students at any level. Since it is possible to classify pollution into four categories: air, water, sight, and sound. With minor variations, this activity could be done with a tape recorder concentrating on sound pollution.

II. Questions

1. Lead to the activity by asking:
    a. Is the student body as a whole aware of our local pollution problems?
    b. What might we do to make them aware?
    c. Does merely telling them about pollution have as great an effect as showing it to them?
    d. Would a slide show, illustrating pollution in our city, town, be interesting to the students?
2. Questions which initiate the activity:
    a. Which sights in our area are particularly offensive?
    b. What pictures would really have an effect on the students in our school?
    c. Have any areas become polluted recently so that they might remember them as they were before?
    d. Are there any areas of potential natural beauty which have been spoiled by pollution?
3. Questions which continue the activity:

a. Should we forcus it on one site, showing it from many angles, times of the day, etc., or should we expand to cover many sights in the area?

b. Are there rivers that become more polluted as you pioneered downstream so that you could show a progression from beauty to pollution?

c. Should we have a sound track to accompany the slides?

d. Should we break up into groups in order to produce the show (i.e., editors, directors, photographers, sound coordinators, projection men, tape or record technicians, etc.)?

4. Questions which help the teacher evaluate the students' efforts:

   a. Does the student try to produce a show which will have an effect on others or is he merely doing what he thinks is interesting? (Of course, he could be doing both successfully.)

   b. How did the students and teachers in the audience react?

   c. Did any long-term projects result from the assembly?

   d. Were these or other students motivated to become involved in further assembly programs in the school?

III. Equipment

1. Cameras

2. Projector and screen

3. Tape recorder or record player (if a sound track will accompany slides)

IV. Procedure

1. The organization should be accomplished in the classroom. The activity can be accomplished in two ways depending on your circumstances. A class field trip approach may be utilized to take the pictures or students may be organized to take the pictures on their own time after school.

2. The students should agree on the total impact they wish to create on the audience and conscientiously strive for it. Most of this will occur during editing and arranging of the slides and coordinating of sound.

3. Sufficient time must be allowed for the slides to be developed and returned.

4. A date must be arranged for the assembly so that the students have a goal and real purpose to work towards.

5. After slides are obtained, the real work begins. They must be arranged and edited to create the desired effect. It may sometimes even be necessary to cut out good slides if there is an overabundance; one or two slides of certain scenes are sometimes more shocking than a dozen. The level of sophistication in coordinating sound and slides will vary according to available equipment and the students' talents; however, they should be aware that the two do interact with each other and if used carefully can become a real asset to the production.

6. There may or may not be any introduction or narration, depending again on the total effect desired by the students.

V. Limitations

Most schools have slide projectors as well as tape recorders or record players. Many suitable cameras are available or, if not, either the teacher, the students, or their parents can usually make one or several available for use. The class may decide to share the cost of having the slides developed or the school may have money available for this purpose. If none of the above is true, try asing the local camera store to lend you a camera and necessary equipment. In short, equipment is not a limitation. However, some problems may be encountered in travel if the sites chosen are not within walking distance. The problems here depend on the size of the class of the group actually doing the photography. Car pools might be organized among the parents and the group can be broken down into smaller units. Perhaps each unit could be in charge of photographing only one site thus reducing the total number who must visit each site.

Role Playing in Water Quality Management

I. Introduction

This activity is designed to familiarize students of 7th through 12th grade level and up with the function of local government and how they can take part in a town's decision making process. The setting is the local Town Hall where a special meeting has been called to consider the proposal that motor boating be banned on a nearby lake.

II. Questions

1. To lead into the activity, ask:

   What type of people would you expect to find present at a local town meeting on this issue?

2. To initiate and continue the activity, ask:

   a. Why would these people act and think as they do?

   b. Where could you find information on each character role?

   c. Which character would you like to be (followed by character assignments)?

3. To continue the activity, ask the students:

   Why they are playing the roles the way they are?

4. To evaluate the activity, ask the students to write a reaction paper. Note whether they really understand what was going on. Recapitulate the activity with the students to assure that they followed the development.

   If a tape recording has been made, this will be helpful. If more than one class has been recorded, play the tapes so that the classes may compare their activities.

III. Equipment

A tape recorder

IV. Procedure

1. Students are asked to imagine what various special interest actions could be expected to be in attendance at the town meeting and what statistics and facts these people might use to support their position.

2. Students are encouraged to identify with one of these factions by imagining themselves in this role for a few days prior to the actual meeting.

3. Follow these tips on parliamentary procedure:

   a. Always wait until the moderator has recognized you before you begin to take the floor.

   b. Always stand when speaking.

   c. Always be courteous as you present your argument. Do not state opinions without being able to draw examples and give proof. Be accurate about dates and statistics.

   d. Do not ask a question directly to or speak to other members in the audience - always put such matters through the Chair.

   e. If you propose an amendment to the article in question, do not forget that the amendment must be prepared as a motion, seconded and then voted upon separately before going to the original question for ratification.

   f. Address the moderator as Mr. Chairman or Mr. Moderator.

   g. If there are many people trying to be recognized at the same time, you must stand and wait until you have an opportunity to speak.

   h. You may through the Chair ask for an opinion from any of the local town officials (i.e., town counsel, local board of health official, local planning board official, town engineer).

V. Suggested Characters to Use

1. Chamber of Commerce president or member.

2. Members of a rapidly organized group.

3. Local members of real estate and brokerage firms.

4. A representative from your school (pick your own character).

5. A private lot and boat owner.

6. An old resident.

7. A poorly-motivated individual.

8. Local representative of the John Birch Society.

9. Representative of local Conservation Committee.

10. Moderator of the town meeting.

VI. Limitations

1. Students may have no experience in role playing or parliamentary discussion. It may be useful to spend 10 minutes in a dry run dealing with the suggested issue.

2. A student with a rather forceful personality is needed as the moderator.

3. Students must have the time to obtain a thorough knowledge of their role and how it relates to the issue in order to guarantee enthusiastic participation.

Social and Political Factors in Water Quality Management

Orientation Program For the Study of Water Pollution

I Introduction

This activity is set up as a discussion for a group orientation to the study of water pollution. The group can be a traditional class. It could also be a community group, e.g. students from several high schools that do not offer a course in water pollution. The questions should stimulate the group into shaping a skeleton from which the leader can plan a study agreeable to all. It would be helpful to get through the whole activity in one session. However, the rate of progression must be determined by the group. Tape recording the discussion would have value, so the group leader could use it as a reference in the future. The questions are set up under the precept that the group will be situated by a polluted body of water. Perhaps it will be the one the group decides to study. This natural setting should act as a motivating device, as seeing the problem would increase awareness and hopefully concern among the group.

II Questions

These questions are here to provide thought provoking topics for discussion. The first three sections play a specific role in the progression of the orientation.

1. To lead into the activity--These questions are here to "set the stage." They are intended to lead the group into an atmosphere of concentration on the subject of water

pollution. They lead into the real investigation.

a. What is pollution?

b. Can you identify by sight any pollution in this water?

c. Are natural things, like leaves and twigs pollution?

d. How is a scientific approach to the problem relevant?

e. What can science tell us about the problem?

f. Can this information help us to solve the problem?

g. How can data and facts help us?

h. Why is a social approach important?

i. How can a social approach help to solve the problem?

j. How can public relations help with a commercial approach to fighting pollution?

k. On which commercial enterprises should there be focusing?

l. What type of public relations is important?

m. Reflecting recent months, pollution plays an important role in politics. How can politics influence pollution?

n. How can his outlook on pollution affect the fate of a politician?

2. To initiate the activity - The trend should be set in a meaningful direction at this point. Discussion now centers about the objectives of the group. These shall be recognized by covering the points to each numbered theme question.

a. Should we study a specific body of water?

b. What would you like to find out about the pollution of this water?

  - chemical
  - bacterial
  - historical
  - aquatic life
  - public influence

c. Are we going to try to solve the pollution problem?

  - (apply what was discussed in A)
  - when

d. How shall we divide the group, if at all?

  - scientific
  - social
  - commercial
  - legislative
  - political

e. Whom shall we involve in fighting this pollution?

  - peers
  - family
  - community

f. What type of information shall we request?

What commercial enterprises shall we contact?

- only water polluters
- any polluters
- research agencies
- factories
- small enterprises

g. What information shall we seek?

- history
- general information
- a role we can assume now

h. What shall our group objective be?

- (tie together what was discussed)

3. To continue the activity - Now that the atmosphere is set and the group objectives recognized, these questions shall focus on planning the group's activities. The extent of the use of the questions will vary, especially in the case of high school students. Many will have to have been answered by other than the group in preparation of a type of contract, be it a community group.

   a. Where shall we begin?

   - (introduce limitations set by authorities, be it necessary)
   - frequency of group sessions

-(summarize B and make it concrete)

-independent work

-funding

-publicity

4. To evaluate the students performance - These questions can be applied to a classroom situation if the need for an evaluation persists. If it is a community group, this evaluation will probably be unnecessary. The leader will have to evaluate a group of high school students if their schools request it. Evaluation may also be necessary if credit is to be given for the study.

    a. Did the group member help set a meaningful trend to the discussion?

    b. Did he (she) make specific personal objectives of the study?

    c. Did he (she) help with the setting of the group objective?

    d. Did he (she) introduce relevant discussion matter not included in the outline?

III Equipment: The equipment used should be decided by the leader. Some may prefer to keep the whole orientation a discussion. Others may find (preferably) non-scientific aids helpful.

Listed below are a few suggestions:

1. Should the students desire to observe the water more closely, the following supplies may prove useful:

   -bucket
   -rope
   -hand lens
   -old cloth (as a net)
   -tin cans
   -plastic bags
   -jars or bottles

2. Current mass media about pollution may or may not prove helpful through the orientation.

IV Procedure: Begin the orientation with questions. Although they need not be carried out exactly, the questions are prepared to facilitate discussion of relevant matter. The leader must "play it by ear", as each group will be directed differently.

V Past Studies:

1. A discussion held in the natural setting has proved effective at Grymes Memorial School, Orange, Virginia.
2. The Role Play technique has been used with great success at Nottingham Academy in Buffalo, N.Y. Its use fosters understanding of various situations and opinions among students. It is a technique especially good for a student who refuses to try to understand a situation.

3. It is important that the students have an understanding of the problem of pollution. A raw scientific approach without any orientation is more apt to "fail" than a study where the students actually understand the significance of any scientific methods before they begin.
4. Notice the word leader is substituted for teacher. A study of water pollution is something new and different to most students. It is more important to learn about it than be taught about it. However, the need for an experienced moderator still exists. This person may or may not be a "teacher". Hopefully, the teamwork that should result will put all group members on the same level, regardless of their age.
5. Role playing activities
    a. A constant consumer of high phosphate detergents arguing about detergents. (If others are introduced, the argument should become a discussion.)
        (1) High phosphate detergent consumer

        -if phosphates are that bad the government should outlaw their use

        -the laundry must be clean, and there are no comparable substitutes

        -phosphates tend to make the water 'wetter', and this is necessary in hard water areas especially

-I have to use up the detergents I've already purchased

(2) Anti-pollution conscious consumer

-phosphates are a main contributor to algae growth and increased bacteria growth, thus causing eutrophication.

-it is up to the individual to fight pollution to the best of his ability.

-which do you value more - clean clothes or clean water?

-if we don't purchase them, store owners and manufacturers will act quicker.

(3) Detergent Manufacturer

-research has been going on for many years.

-automatically banning phosphate detergents would present serious problems.

-housewives are spoiled by modern detergents and won't settle for soap

-if housewives were really so anti-pollutior, why are they still buying high phosphate detergents?

(4) Grocery store owner

-must stock all different products so a consumer may purchase according to individual needs

-obligation to provide an outlet for manufactured products

-must not let viewpoint overpower the wants of the consumers

-competitive reasons force me to stock favorite laundry aids

b. A purchaser of brightly colored tissue products which contain non-biodegradable dyes is angry because the store she patronizes stocks only white tissue now. This is a discussion among any number of the four or more possible role players.

(1) Angry Purchaser

-these products brighten up the bathroom decor

-if they are banned, so should other luxury items that pollute worse

-these products are much softer

-somebody has to buy them

(2) Anti-pollution crusader

-unnecessary pollution created

-white tissue products do the job just as well

-individuals should fight pollution to the best of their ability

-such products a waste of money

(3) Manufacturer

-color is a way of brightening life

-nobody is obliged to buy them

-worse dye pollution from fabric mills etc.

-manufacturing not stopped for economic reasons

(4) Store owner

-color disgression is not right

-comparable products that pollute less are still stocked

-unsightly dye pollution is created in manufacturing-let's stop as much as we can

-hint to manufacturers such products unnecessary luxuries

c. A boat owner is upset with the new law concerning sewage disposal from boats. He is discussing it with a friend.

(1) The Law

-illegal to discharge sewage from watercraft into water

-head may be sealed permanently and still comply with the law

-all users of the state's waterways must comply.

(2) Boat Owner

-silly law to bring sewage back to land only to receive inadequate or no treatment.

-pollution control device too expensive for the seldom used head.

-out of state boaters are being cheated.

(3) Anti-pollution crusader

-better to have sewage concentrated than discharged throughout waterways.

-other states will look up and form better standards.

-obligation of all boaters to comply.

The role plays should then be analyzed:

-did the person play his role all the way through?

-could a concensus be attained?

-were any dependencies among various roles cited?

-were resolutions suggested? Could they be suggested?

VI Limitations

1. In a community group, the problem might arise of the participants not being acquainted with each other. The leader must be prepared to help resolve this problem, as a study of water pollution requires real team work. The discussion approach which this particular paper deals with should help relieve this obstacle a bit.
2. Students may have trouble understanding problems of fighting pollution. It is important that they understand the viewpoints of those involved in their professions. This is an area where they assume the role of a designated position.

In a given situation they are to work out a problem verbally, trying to adhere to their role, under group observation. It is interesting and often advantageous to have the students exchange roles about half way through. The examples below are representative of typical problems encountered in an effort to fight pollution. They are accompanied by points that often occur in the situation. There are undoubtedly supplements. The points given are not paralleled.

VII Bibliography and Resources

This paper was put together by drawing on experiences. No specific references were consulted.

To initiate and sustain an activity such as this, the best resources are current mass media.

The following general questions may serve to focus on the scope of inquiry in this chapter. Let "X" equal the particular human activity under investigation.

1. What is the influence of "X" on the nitrogen cycle in your area?
2. What is the influence of "X" on the hydrologic cycle in your area?
3. How do the economic factors of "X" influence its impact on environmental quality?
4. What is the general public's attitude toward the impact "X" has on the environment?
5. What is the legal situation pertaining to "X"? Are the laws sufficient to preserve the environment? Are the enforcement procedures adequate?
6. What are the roadblocks to the lessening of "X's" impact on the environment?

The following resources will be found useful throughout the entire section. Resources of particular interest are listed at the close of each activity.

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Community Survey

I. Introduction

This activity is intended to arouse the students' interest in the effects of human activities on a body of water. This is done by locating sites which might be sources of pollution; collecting samples for the necessary tests; running the tests; gathering the data; and making tentative conclusions. Then, by contacting persons associated with the community, help them to understand what their water problems are. Any level high school student can complete this activity.

II. Questions

1. Lead to the activity by asking:
    - a. What are the possible sources of pollution in a body of water?
    - b. What is the effect of a town's sewage and other effluents on adjacent bodies of water?
2. Initiate the activity by asking students:
    - a. What are the sources of sewage and other effluents and specifically where are they located?
    - b. What types of tests should be utilized?
    - c. What sites are to be used in the testing process and are they representative?
3. Continue the activity with these questions:
    - a. Do we have enough data to reach a conclusion?
    - b. How will we use our data to arouse public interest?
    - c. Should letters be sent, people interviewed, information be handed out, etc.?
4. Evaluate the activity by considering:
    - a. Did the students understand the testing procedure and purpose?

b. Did the students eliminate variables that could produce errors in the data?

c. Are the students aware of the implications brought about by improper sewage and other effluent disposal practices?

d. Are the students cognizant of possible approaches that can be used to initiate public concern?

Pollution and Recovery

I. Introduction

In this activity students will become interested in seeing the effects of a town or city on a given waterway. The fieldwork is uncomplicated, consisting of sampling the water above and below the community. The most striking results will be obtained by testing above and below a town or city that has a substantial amount of industry with little, or no waste processing equipment. Two questions should be answered in this survey: what influence does industrial waste have on the over-all environment of a waterway and what is the recovery-rate of a stream as the distance from the effluent is increased? A follow-up investigation should be undertaken to study the influence of the factors as they apply to recovery rate.

II. Questions

1. Lead the activity by asking: What effect industrial waste has on the over-all quality of this water system?

2. Initiate the activity by asking:

   a. Where should your water samples be taken in this stream?

   b. Why did you choose these locations? (This should lead to a discussion as to the desirability of collecting above, immediately below, and a considerable distance below the effluent.)

3. Continue the activity by asking:

   a. Do you notice any prominant physical or biological changes in the immediate environment?

   b. If we came back here tomorrow and collected samples, do you think there would be a considerable variance in data?

   c. What tests, other than chemical, would prove helpful in an over-all evaluation of this stream?

4. Questions such as these may help to evaluate the efforts of the students:

   a. Did the investigation hold the interest of the majority of the students?

   b. Did they seem eager to enlarge on the subject; as to which chemicals were doing the most damage to the system, where the most pollution was coming from, what action should come next?

   c. Did all, or most, of the students enter eagerly into the task of testing the samples from the three sites? (See II 2 b)

III. Equipment

1. Other than the laboratory testing kits very little is needed to carry out this investigation. The students should be encouraged to plan most of the procedures, and collect the needed fieldwork equipment.

2. Sample equipment might include:

   a. Collection bottles and fixing solutions for dissolved oxygen tests (Winkler Method)

   b. Collection bottles, any size, for general samples

   c. Collection bottles for bacteria; so labeled

   d. Testing kits and equipment, (i.e., Hack, Delta, or LaMotte kits, pH testing kit, pipettes and chemicals for Winkler tests for dissolved oxygen) DO meter (for comparison with Winkler test)

IV. Procedure

1. Collect water samples from 3 locations on the river; above, immediately below, and a considerable distance below the indisutrial waste.

2. Take a meter reading, if possible, for dissolved 0_2 at each location.

3. Fix the oxygen in one bottle from each location with solutions of manganese sulfate, and alkali-iodide-azide. (For Winkler test --dissolved oxygen.)

4. Collect bacteria samples from each location.

5. Return to lab and make tests.

V. Previous Studies

1. Previous studies of this investigation have pointed out to the students which dissolved solids are most closely allied with industrial waste.

2. Some students are surprised that a stream that shows a high degree of pollution just below an effluent shows a remarkable degree of recovery over a comparatively short distance.

3. It has been noted that with most students there is a great desire to investigate the cause of each pollutant, and to work toward finding ways to eliminate the source. This investigation stimulates interest in over-all "ecotactics."

VI. Limitations

Other than the bacteria cultures, which are demanding, very few factors can hinder significant results from this investigation. Extreme accuracy is not important, as the comparison between above and below samples is very conclusive. Transportation to collection sites is the only real concern. Suitable clothing should be worn. Hands should be thoroughly cleaned after collecting heavily polluted water.

VII. Bibliography

Klein, L., River Pollution 3 Control, Butterworth & Co., London, England, 1966. It gives very complete coverage of total river pollution problems and is an advanced text.

Machenthum, K.M., The Practice of Water Pollution Biology, Department of the Interior, Washington, D.C., 1969. This may be of some use for sampling techniques. It has little to offer over the testing kits.

McKee, J.E., and H.W. Wolf, Water Quality Criteria, State Water Quality Control Board, Sacramento, Calif., 1963. This is a very complete compilation of standards for all industrial and household uses of water. Standards for most stages are listed according to water usage.

Ruttner, F., Fundamentals of Liminology, University of Toronto Press, Toronto, Canada, 1969. Pages 56 to 104 cover all dissolved solids fround in fresh water but is quite involved for the beginning student.

U.S. Department of the Interior, Pollution Control Administration, Biological Field Investigation Data for Water Pollution Surveys, U.S. Government Printing Office, Washington, D.C. This is a very fine booklet for general use on water pollution and costs only seventy cents. It has a very complete list of ecologic terminology and good chemical tables, especially on dilution.

Sewage Treatment

I. Introduction

In this activity students learn about sewage and waste treatment. The students learn how sewage is processed in their town and in neighboring communities. New laboratory techniques and equipment will be introduced which will enable students to determine the efficiency of various sewage treatment procedures and to appreciate, in a more precise way, the problems involved in an important but often neglected or unnoticed part of everyone's life. The time required may vary from two to four periods or longer depending on the difficulty of selective procedure, student interest, and time and equipment available. The activity is designed for students from 7th grade and up.

II. Questions

1. To lead the activity ask: What happens to the sewage and waste waters in your community after leaving their point of origin?

2. To initiate the activity ask:

   a. What type (primary, secondary, tertiary) or waste treatment facilities does your community have? (Consult local authorities, i.e., local health departments and sanitary engineers.)

   b. Are all types of wastes (sewage, runoff) treated in the same way?

   c. How effective is this treatment?

   d. Could it be improved? How?

3. To continue the activity ask:

   a. Are the methods of elimination of pollutants which you have encountered the most effective methods possible?

   b. If not, why not?

   c. What tests can be performed to determine the effectiveness of treatment plants?

4. To evaluate the student's performance ask:
   a. Do you consider the sewage treatment in your community adequate?

    b. What can we as individuals or members of groups do to help improve sewage treatment methods?

III. Equipment

1. Introductory Level
    - a. Sample bottles
    - b. Microscope
    - c. Hach or Delta kit
    - d. Aquatic identification books for identifying microorganisms
2. Advanced Level
    - a. Same as above
    - b. Millipore equipment or standard bacteriological materials
    - c. Titration equipment for Winkler, BOD
    - d. Materials for constructing a model treatment system

IV. Procedures

1. Introductory Level
    - a. Using microscopes and identification books identify the organisms found in samples.
    - b. Using the Hach or Delta kit determine the level of nitrates in the water. Determine why this level is so important.
    - c. Draw diagrams of the local treatment plant.
    - d. Determine pH. Why is it important in processing sewage?
2. Advanced Level
    - a. Same as above
    - b. Using the Hach and Delta, determine the levels for dissolved solids you feel are important in sewage treatment based on what you have learned, in preparing for this activity and your study of the treatment plant.

c. Using Millipore filter technique, or other methods, determine the level of bacteria before and after treatment. Also determine why this level is important.

d. Determine how bacteria are used in sewage treatment. (Discussion)

e. Determine the level of DO, IDOD, BOD in water before and after treatment, and in the body of water into which the treated sewage is dumped. Disucss the significance of the results (refer to Standard Methods for technique).

f. Build a model sewage treatment plant.

V. Past Studies

1. A group of students from Quincy, Mass., found their bay to be suffering from rapid biological aging (eutrophication). Also, it was being polluted by "storm" drains from a combination storm-sewage system. They studied the advantages and disadvantages of secondary treatment, the dangers of daily chlorination, and the problems of algae.

2. Another group of students from Quincy made a study of the effects of sludge being pumped into the bay at a rate of 2 million gallons a day. They concern themselves with BOD, eutrophication and floating solids.

VI. Limitations

If there is no treatment plant in your area it will be necessary to take field trips. Movies and books may have to replace the primary learning and experience of visiting the plant. Supplemental equipment may consist of: paper chromatography; standard analytic procedures, quantitative and qualitative analyses, etc.

VII. Bibliography

1. Introduction to Sewage Treatment.

a. Pelczar, Michael J., and Roger D. Reid, Microbiology, McGraw-Hill Book Co., New York City, 1965. This is an excellent source for an outline of sewage treatment. Pages 511-522 discuss the biological and chemical characteristics of sewage and outline Primary and Secondary Treatment.

The following Bibliography is provided to give some references which deal specifically with water quality as it relates to our program. Many of these books can be used directly by the student while others must be interpreted by the teachers. Where we felt it was necessary, an annotation was provided.

Manual of Wastewater Operations: Texas
Water Utilities Association. (1971) Texas
State Department of Health.
Lancaster Press, Inc., Lancaster, Penn.
This manual is written for
wastewater plant operators
and is a technical manual for them.

Sewage Works Operation. Units I, II, III.
I. N. Ronhovde. Water and Sewage
Works Training. Eng. Extension
Service, Texas A&M University.

A Primer on Waste Water Treatment.
Environmental Protection Agency.
This contains basic information on
Basic Wastewater Treatment.
Good Pictures. 55¢

First and Second Readers on Water Quality, 1967
Joe P. Tller. Water Quality Board.
This is contained in your notebook. More
are available from T.W.Q.B. upon request.

Standard Methods for the Examination of Water and Wastewater. 13th Edition. 1971. American Public Health Association. A.P.H.A. New York. This contains all accepted analytical, Biological and Chemical methods used.

Limnological Methods. 1948. P. S. Welch. McGraw-Hill, New York.

The Biology of Polluted Water. 1960. H.B.N. Hynes. Liverpool Univ. Press, Liverpool.

The Ecology of Running Waters. 1970. H.B.N. Hynes. Univ. Toronto Press.

Ecology of Inland Waters and Estuaries. 1961. G. K. Reid. Reinhold Publ. Corp. New York.

Eutrophication: Causes, Consequences and Correctives. Proceedings of a Symposium. 1969. National Academy of Sciences. Washington, D.C. Available From: Printing & Publishing Office, National Academy of Sciences, 2101 Constitution Ave., Washington, D.C. 20418.

Freshwater Invertebrates of the United States. 1953. Robert W. Pennak. The Ronald Press Company, New York.
Contains keys to the invertebrates plus good general information.

The Freshwater Fishes (How to Know). 2nd edition. 1969 (Paper).
Samuel Eddy. Wm. C. Brown Company Publishers. The Pictured - Key Nature Series.

Keys to Water Quality Indicative Organisms. (Southwestern United States). 1968. Fred K. Parrish (Editor). Fed. Wat. Poll. Cont. Adm. (Now E.P.A.)

Biology and Water Pollution Control. 1971. Charles E. Warren. W. B. Saunders Company, Philadelphia.

Contains a good summation of Water Pollution to Publication Date.

Aquatic and Wetland Plants of Southwestern United States. 1972. Donovan S. Correll & Helen B. Correll. E. P. A.

Journals

Journal Federal Water Pollution Control Federation. This Journal contains advanced articles dealing with all aspects of water pollution.

Limnology and Oceanography - Technical articles

Hydrobiologia - Technical papers, more Biologically oriented.

American Scientist - Wide range of papers of a more general nature.

National Biology Teacher - Techniques, methods and idealogy of biology teaching. Good for high school teaching.

TEACHER WORKSHOP EVALUATION FORM

(Please circle, fill in or otherwise provide the necessary information)

NAME________________________________

1. My major fields of study in college were ____________________________
   ____

2. The subject (s) which I am presently teaching is(are)______________
   ____

3. I do do not possess a Teaching Certificate

4. I consider my Educational backgroud and general knowledge involving water quality to be:
   A. poor
   B. fair
   C. good
   D. excellent

5. I have made attempts to relate my teaching to some general environmental problems.
   A. yes
   B. no

6. I have made attempts to relate my teaching specifically to water quality problems.
   A. yes
   B. no

7. I believe that this course has provided pertinent information which can aid in my relating water quality to my teaching curriculum.
   A. yes
   B. no

8. Compared with what I expected to get from this program, I feel I got:
   A. Far more than I expected
   B. More than I expected
   C. What I expected
   D. Less than I expected
   E. Far less than I expected

9. Please rate the following sections with respect to:
A. Presentation and general enjoyability
B. Applicability to teaching
CIRCLE THE LETTER & NUMBER WHICH APPLY

	Poor		Average		Excellent
Presentation & enjoyability	1	2	3	4	5
Applicability to teaching	a	b	c	d	e
1) Water Awareness Test					
	1	2	3	4	5
	a	b	c	d	e
2) Role of Government					
	1	2	3	4	5
	a	b	c	d	e
3) Water Quality Parameters					
	1	2	3	4	5
	a	b	c	d	e
4) Wastewater Treatment Methods	1	2	3	4	5
	a	b	c	d	e
5) Biological Responses To Water Pollution	1	2	3	4	5
	a	b	c	d	e
6) Social and Economic Factor	1	2	3	4	5
	a	b	c	d	e

10. What can the Environmental Education and training section do to further help your teaching programs dealing with water quality?

11. Please write below any additional comments which you wish to make.